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Minimum weight design of frames using sway subassemblage theory

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MINIMUM WEIGHT DESIGN OF FRAMES USING SWAY SUBASSEMBLAGE THEORY

by

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ABSTRACT

This thesis considers the theoretical development of a minimum weight design procedure for unbraced multi-story frames which are subjected to combined gravity and wind loads.

The lateral load versus sway deflection of unbraced frames which are designed by the moment balancing method are discussed first. Then the load-deflection behavior of a 3-bay 10-story frame which was designed by the moment balancing method is analyzed using the sway subassemblage method[1,2] and a second-order elastic-plastic method of analysis.[3] The behavior of this unbraced frame under working load values of the combined loads is then discussed. It is shown that the sway deflection of the frame under the working loads is somewhat larger than usually considered practical. Furthermore, it is shown that unbraced multi-story frames designed by the moment balancing method may not in general achieve acceptable sway deflections at working load.

The minimum weight design method using sway subassemblage theory is then described. This method determines the minimum weight of beams and columns in an unbraced multi-story frame considering the following design constraints.

1. A specified maximum sway deflection of a story under combined working loads.
2. No plastic hinges at the working load level of the combined loads.

Once the minimum weight design of the frame has been achieved, the sway subassemblage method of analysis is then used to determine if the frame has the required capacity under factored combined loads. A computer program written in Fortran IV for the minimum weight design of an unbraced frame subject to the above constraints is presented.

1. INTRODUCTION

An unbraced multi-story frame should be designed to meet the following five conditions.

1. Failure does not occur before attainment of the factored gravity load,
2. failure does not occur before attainment of the factored combined gravity and wind loads,
3. no plastic hinges occur under the working load value of the gravity and the combined wind and gravity loads,
4. the sway deflection of each story of the frame under the working load value of the combined loads should be restricted to a maximum value, and
5. a minimum weight design with respect to the beams and columns should be achieved.

In general, an unbraced multi-story frame are usually designed by trial and error procedures which involve the following three steps[4];

1. The preliminary design; the selection of tentative beam and column sizes.
2. The analysis; the determination of the adequacy of members selected in step (1) based on strength and stiffness.
3. The revision; the revision of one or more members based on the results of the analysis or on other factors such as minimum weight or economy.

For the preliminary design, the moment balancing method of analysis can be used. However only an estimate of the P-Δ effects is included at this point. The sway subassemblage method of analysis has been developed to check the adequacy of the preliminary design based on frame strength and stiffness.[1,2] The P-Δ effect can be determined from such an analysis[6] and can be compared with that assumed in the preliminary design by moment balancing method. Based on the results of the analysis, a revision of the preliminary design can be made. A subsequent analysis is then required.

However, there has been no rational basis developed to date on which to make the required revision of the preliminary design and at the same time meet all the previous design conditions.

This thesis presents a method of designing unbraced multi-story frames for the combined gravity and wind load condition which will meet these design conditions. It utilizes both the moment balancing and the sway subassemblage methods previously developed.[1,5] In addition it develops a minimum weight design procedure which is based on the basic assumptions of the sway subassemblage method.[1]

The nature of problem of designing frames for minimum weight has been clarified considerably by the work of J. Foulkes.[7] This work has been extended by further investigations.[8,9] It was assumed in Ref. 7 that

1. The full plastic moments of the members are unaffected by shear force and axial thrust,
2. an infinite range of sections is available, and
3. the curve which represents the relation between the weight per unit length and the full plastic moment of the section can be replaced by a straight line.

Messrs. Moshe F. Rubinstein and John Karagozian[10] discuss the preliminary design of an unbraced frame on a minimum weight basis using

using the following assumptions:

1. Plastic hinges form only in the beams.
2. A linear variation of member sizes with story height is assumed.
3. The contributions of the beams and columns to the flexibility of a building frame are separated and a conservative ratio between those contributions is established.

They conclude that it is more effecient to provide increased stiffness of the beams in the exterior bays of an unbraced frames.

T. M. Murray also treats the optimum design of unbraced frames. However, this work does not consider either the effect of P-Δ moments or the sway limitation at the working loads.

In the minimum weight method of design to be developed in this thesis, the following conditions are assumed for the frame and loading (in addition to the assumptions on which the sway subassemblage method of analysis are based).

1. The full plastic moments of the members are reduced by the axial thrusts,
2. Only those shapes listed in the AISC Manual of Steel Construction[12] are available,
3. The effect of P-Δ moments in the behavior of the frame are considered,
4. The members selected are adequate for the factored gravity load condition,
5. A working load sway limitation under the combined loads is considered,
6. No plastic hinges occur under the working loads, and

7. A minimum weight design of the frame at working load values of the combined loads is achieved.

Since the minimum weight design procedure does not consider frame strength and stiffness under the factored combined gravity and wind loads, minimum weight design is then checked using the sway subassemblage method of analysis. If the frame does not achieve the required capacity under the factored combined loads, another minimum weight design can be performed. To achieve increased factored load capacity of the story under combined loads, the minimum weight design can be repeated using either of the following criterion:

1. A smaller working load sway limitation is specified, or
2. The same working load sway limitation is retained but the formation of plastic hinges is delayed to a specified level of loads greater than the working load level.

To illustrate the design procedure developed in this thesis, Frame B of Ref. 6, will be used.

2. PRELIMINARY DESIGN OF FRAME B BY MOMENT BALANCING METHOD

The load deflection behavior of Frame B as designed in Ref. 6 will be examined under both working and factored combined loads using the sway subassemblage method of analysis. The dimensions and loading for Frame B are shown in Fig. 2.1. The member sizes determined by the moment balancing method are shown in Fig. 2.2.[6] The axial thrusts in the columns under working and factored combined loads must be estimated before calculating the load deflection behavior of a story. In the sway subassemblage method of analysis, these axial thrusts are assumed to remain constant during application of the wind load. Axial thrusts due to gravity loads can be based on the tributary column area.[13] Axial thrusts due to the wind load however can only be estimated under the desired load level. Several methods for estimating the axial thrusts in the columns either at the working or the factored load level of the wind load will be discussed in this thesis.

Approximate methods of analysis are available for elastic frames, such as the cantilever method.[14] A modified elastic solution for the frame will be used in this thesis to determine the approximate value of the axial thrusts in the columns under working wind loads.

Using the assumptions of the sway subassemblage methods of analysis, a one story assemblage at level n is isolated from an unbraced multi-story frame as shown in Fig. 2.3. The axial thrusts in the columns can be determined by the slope-deflection method of analysis under the following assumptions.

1. The total horizontal shear forces in the columns above and below level n are the same, and

2. The sway deflections for each column are the same.

Table 2.1 shows the axial thrusts in the columns due to wind load determined by this method. Figure 2.4 shows the horizontal load versus sway deflection behaviors under the working gravity load for levels 4, 6, 8 and 10 in Frame B using the sway subassemblage computer program.[15] The vertical axis shows the applied horizontal shear force non-dimensionalized by the working load level of wind load. The horizontal axis shows the deflection index Δ/h of the story where Δ is the sway deflection and h is story height.

Under the factored load level, the axial thrusts in the columns can be determined by assuming the following distribution of bending moments in one story assemblage.

1. The bending moments at the leeward ends of the beams are at the full plastic moment,

2. The bending moments at the windward ends of the beams or within the spans, whichever is applicable are at the full plastic moment, and

3. At each joint the sum of the bending moments in the beams is equal to or less than ΣM_{pc} for the columns.

Table 2.2 shows the axial thrusts in columns due to wind load by this method. Figure 2.5 shows the horizontal load versus sway deflection behavior of levels 4, 6, 8 and 10 of Frame B for factored combined loads.

The following observations can be made from Figs. 2.4 and 2.5.

1. The sway deflections under the working load level of the combined loads are too large for practical designs.
2. Plastic hinges form considerably before the attainment of working loads in levels 4 and 6.
3. The strength of level 4 and 6 are considerably below the desired factored load level of the combined loads.

In Figs. 2.6 and 2.7, curve 1 shows the horizontal force versus sway deflection behavior for constant factored gravity load as calculated by the sway subassemblage method of analysis. Curve 2 shows the same behavior for proportionally increasing gravity load with the wind load calculated by step by step method for gradually increasing gravity load using the sway subassemblage method of analysis. Curve 3 was obtained by an "exact" second order elastic-plastic analysis.[3] For level 6 the degree of approximation using the sway subassemblage method is not too large. Therefore, the strength of level 6 under the constant factored gravity load as shown by curve 1 should be fairly accurate. It can be seen that considerably lower strength was obtained at level 6 when gravity loads were held constant at their factored values.

A similar comparison was made for level 8 as shown in Fig. 2.7. In this case curves 2 and 3 indicate close agreement between the "exact" and the sway subassemblage methods. For level 8 , then, curve 1 which was obtained for constant factored gravity load should be very accurate. However, considerably larger strength under non-proportional load is available at level 8. It can be noted however from Fig. 2.7 that under the factored (1.3) values of combined gravity and wind loads, all three curves are in close agreement.

3. MINIMUM WEIGHT DESIGN OF FRAMES

3.1 Shear Distribution Factors for a Sway Subassemblage

Fig. 2.3 shows the loading condition for a one story assemblage isolated from an unbraced multi-story frame. The axial forces in the columns are determined as discussed in Chapter 2. The total shear force due to wind loading can be calculated from the loading condition. However, the distribution of shear force to each column must be determined. The one story assemblage shown in Fig. 2.3 can be divided into four sway subassemblages[1] as shown in Fig. 3.1. Figure 3.2 shows a typical interior sway subassemblage. The restraining coefficients $K_{i-1,i}$ and K_{ji} in Fig. 3.2 can be approximately expressed by Eqs. 54 and 56 in Ref. 1.

The relationship between the horizontal shear force, $\lambda_i Q_n$ and deflection index $\rho = \Delta/h$ in Fig. 3.2 can be expressed by

$$\lambda_i Q_n = \frac{\left(\frac{I_{i-1,i}}{L_{i-1,i}} \xi_{i-1} + \frac{I_{ij}}{L_{ij}} \xi_{i+1}\right)\left(4 \frac{EI_i}{h} U_i - P_i h\right) - U_i P_i h \frac{I_i}{h}}{\left(\frac{I_{i-1,i}}{L_{i-1,i}} \xi_{i-1} + \frac{I_{ij}}{L_{ij}} \xi_{i+1} + \frac{I_i}{h} U_i\right) h} \rho \qquad (3.1)$$

where
$$\xi_{i-1} = \frac{3 - K_{i-1,i}}{4 - K_{i-1,i}}$$

$$\xi_{i+1} = \frac{3 - K_{ji}}{4 - K_{ji}}$$

$$U_i = \frac{1}{C_i}(C_i^2 - S_i^2)$$

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where
$$\xi_{i-1} = \frac{3 - K_{i-1,i}}{4 - K_{i-1,i}}$$

$$\xi_{i+1} = \frac{3 - K_{ji}}{4 - K_{ji}}$$

$$U_i = \frac{1}{C_i} (C_i^2 - S_i^2)$$

$$C_i = \frac{c_i}{c_i^2 - s_i^2}$$

$$S_i = \frac{s_i}{c_i^2 - s_i^2}$$

$$c_i = \frac{1}{\phi^2}(\phi \coth \phi - 1)$$

$$s_i = \frac{1}{\phi^2}\left(1 - \frac{\phi}{\sinh\phi}\right)$$

$$\phi = \frac{h}{2}\sqrt{\frac{P_i}{EI_i}}$$

The derivation of Eq. 3.1 is given in Appendix I.

The sway deflections of each sway subassemblage under the applied horizontal shear force Q_n are assumed to be equal. Also the sum of the column shears for each sway subassemblage is equal to the total applied shear force Q_n. Using these relations, the horizontal shear distribution factor λ_i can be determined as follows:

$$\lambda_i = \frac{\dfrac{\left(\dfrac{I_{i-1,i}}{L_{i-1,i}}\xi_{i-1} + \dfrac{I_{ij}}{L_{ij}}\xi_{i+1}\right)\left(4\dfrac{EI_i}{h}U_i - P_i h\right) - U_i P_i h \dfrac{I_i}{h}}{\left(\dfrac{I_{i-1,i}}{L_{i-1,i}}\xi_{i-1} + \dfrac{I_{ij}}{L_{ij}}\xi_{i+1} + \dfrac{I_i}{h}U_i\right) h}}{\sum\limits_{i+1}^{n} \dfrac{\left(\dfrac{I_{i-1,i}}{L_{i-1,i}}\xi_{i-1} + \dfrac{I_{ij}}{L_{ij}}\xi_{i+1}\right)\left(4\dfrac{EI_i}{h}U_i - P_i h\right) - U_i P_i h \dfrac{I_i}{h}}{\left(\dfrac{I_{i-1,i}}{L_{i-1,i}}\xi_{i-1} + \dfrac{I_{ij}}{L_{ij}}\xi_{i+1} + \dfrac{I_i}{h}U_i\right) h}}$$

3.2 The Relationship Between Moment Inertia of Beam and Column for a Constant Sway

Based on Eq. 3.1, the compatibility condition for the interior sway subassemblage shown in Fig. 3.2 for the given horizontal shear force and restricted working load sway ρ is as follows:

$$\lambda_i \left(\frac{I_{i-1,i}}{L_{i-1,i}} \xi_{i-1} + \frac{I_{ij}}{L_{ij}} \xi_{i+1} + \frac{I_i}{h} U_i \right) h\, Q_n = \left(\frac{I_{i-1,i}}{L_{i-1,i}} \xi_{i-1} + \frac{I_{ij}}{L_{ij}} \xi_{i+1} \right)$$

$$\times \left(4 \frac{EI_i}{h} U_i - P_i h \right) \rho - U_i P_i h \frac{I_i}{H} \rho \qquad (3.2)$$

Expressing Eq. 3.2 in terms of the moment of inertia of column I_i which is required for maintaining constant sway P gives

$$\frac{I_i}{h} = \frac{\left(\lambda_i h\, Q_n + \rho\, P_i h\right)\left(\frac{I_{i-1,i}}{L_{i-1,i}} \xi_{i-1} + \frac{I_{ij}}{L_{ij}} \xi_{i+1}\right)}{4EU_i\rho\left(\frac{I_{i-1,i}}{L_{i-1,i}} \xi_{i-1} + \frac{I_{ij}}{L_{ij}} \xi_{i+1}\right) - U_i P_i h\, \rho - \lambda_i\, U_i h\, Q_n} \qquad (3.3)$$

where $\dfrac{I_{i-1,i}}{L_{i-1,i}} \xi_{i-1} + \dfrac{I_{ij}}{L_{ij}} \xi_{i+1} > \dfrac{1}{4E\rho} (P_i h\, P + \lambda_i h\, Q)$

Also expressing Eq. 3.2 in terms of the moment of inertia of the beams which is required for maintaining constant sway P gives

$$\frac{I_{ij}}{L_{ij}} = \frac{4 \frac{EI_i}{h} U_i \rho \frac{I_{i-1,i}}{L_{i-1,i}} \xi_{i-1} - (\lambda_i h\, Q + P_i h \rho) \frac{I_{i-1,i}}{L_{i-1,i}} \xi_{i-1} - (P_i \rho + \lambda\, Q_n)\, U_i h \frac{I_i}{h}}{(\lambda_i h\, Q_n + P_i h\, \rho - 4 \frac{EI_i}{h} U_i\, \rho)\, \xi_{i+1}} \qquad (3.4)$$

where $\dfrac{I_i}{h} > \dfrac{1}{4EU_i\rho} (\lambda_i\, Q_n + P_i\, \rho)\, h$

If the moment of inertia of either the beam or the column in the sway subassemblage shown in Fig. 3.2 is known, the moment of inertia of the other member which maintains the constant sway condition can be found from Eqs. 3.3 or 3.4.

4.3 The Minimum Weight Design Process

The three-step design process for an unbraced multi-story frame has been described previously in Chapter 1. In this article, the following optimum design procedure will be described in accordance with those steps.

1. A frame which is designed by the moment balancing method is taken as the preliminary design.[6]

2. The axial thrusts in the columns due to the working load are calculated using the method described in Chapter 2.

3. The bending moments in the beams and columns are then calculated under the working combined loads.

4. The distribution factors λ_i are calculated by Eq. 3.1 for each one story sway assemblage.

5. Each one story assemblage is then divided into sway subassemblages.

6. The beam and the column for the windward sway subassemblage is first optimized with respect to weight using Eqs. 3.3 and 3.4.

7. The plastic moment condition for the beam and columns determined in step (6) is then checked using the bending moments calculated in step (3).

8. The combination of beam and column which gives a minimum weight and satisfies the plastic moment condition is then selected as the first trial members for the windward sway subassemblage.

9. For the first interior sway subassemblage, the column and leeward beam are then optimized with respect to weight. The windward beam which was previously chosen in step (8) is held constant.

10. All interior sway subassemblages are optimized in the same way preceeding from the windward to the leeward side of the one story assemblage.

11. The column in the leeward sway subassemblage remains. This column is determined by Eq. 3.3 and the plastic moment condition.

After all members of a one story assemblage are determined, the calculation must be repeated from step (3) to (11) using new value of λ_i until convergence is obtained. The previous procedure is carried out for wind from both directions such that all members chosen satisfy the 4 conditions listed in Chapter 1 for the minimum weight design of the frame. The final members obtained are then used when the story is checked for its capacity under factored combined loads.

4. COMPUTER PROGRAM FOR MINIMUM WEIGHT DESIGN OF UNBRACED FRAMES

Based on the minimum weight design method which was described in Chapter 3, a computer program has been written to find the optimum member sizes for an unbraced multi-story frame subjected to combined gravity and wind loads. The program is written in Fortran IV and is limited to rigid, plane, unbraced multi-story frames of up to thirty stories and five bays. At first, the minimum weight member sizes are determined and printed out for one direction of wind load. Then, the member sizes are modified if necessary for the other direction of wind load while maintaining the minimum weight condition. The calculation process follows the sequence described in Chapter 3.

The main program begins by reading the number of stories, the number of bays, story height, span length of bays, gravity loads on beams, flexural modulus, yield stress level of steel and working load sway limitation. Subroutine DATA 1 is called to read the section properties of the American standard shapes for columns and beams[12] which are used for the design of multi-story frames. The preliminary member sizes for the frame determined by the moment balancing method are read by subroutine DATA 2. The axial thrusts in the columns of the frame based on tributary areas are read by subroutine DATA 3. Then, the wind loads for each story are read and the axial forces due to the working wind loads are calculated as described in Chapter 2 by subroutine WINDLD. The section properties of American standard shapes, which were read in subroutine DATA 1 are then arranged in decending order of moment of inertia by subroutine ARRANG. Since for practical frame designs one column shape is usually used for for 2 consecutive stories. The minimum weight calculation of the one story assemblage is performed for every second level starting from the bottom of the frame.

Subroutine DATA 4 arranges the axial forces in columns, moment inertias in beams and columns for a given one story assemblage. The moments of inertia, span lengths and restraint factores of the left and the right sides of a column are arranged in subroutine COEFT. The restraint coefficients of a sway subassemblage are calculated in subroutine RESTRN. The shear distribution factors for each sway subassemblage are calculated in subroutine DISFAC. In subroutine MINWET, each sway subassemblage is optimized with respect to weight as discussed previously, and the plastic moment condition for beams and columns is checked using the bending moment calculated for the previous frame in subroutine CHECK. After all sway subassemblages have been optimized, the first trial members are available for the one story assemblage. The bending moments for the new one story assemblage are calculated and the plastic moment condition is again checked. It also checks for convergence of required member sizes. If one or more of these are not satisfied, the calculation is repeated convergence is obtained. These calculations are performed by subroutine CHECK. After the calculation converge for level n, the calculation moves to level n-2. When the minimum weight calculation are completed for every second one story assemblage, the comparison between the weight of the preliminary frame designed by moment balancing and the minimum weight frame is made.

The new member sizes and the weight of the frame are printed out by subroutine OUTPUT. These member sizes are determined for wind from one direction. The calculation is then repeated for the opposite direction of the wind loads. The data which are needed for calculation for the opposite direction of wind load are rearranged in subroutine TRANSP. The calculation is performed by the same process described previously. The final member sizes for both directions of the wind load are selected on the basis that all member sizes should not be less than the members chosen for wind in either direction. The final member sizes and the weight of the frame are printed out.

5. DESIGN EXAMPLE AND RESULTS

Using the computer program described in Chapter 4 and presented in Appendix II, the minimum weight design of Frame B was obtained for assumed working load sway limitations of $\rho_L = \Delta_L/h = 0.001$, 0.0015, 0.002, 0.0025, 0.003 and 0.004. The resulting designs for $\rho_L = 0.002$, 0.0025, 0.003 and 0.004 are shown in Figs. 5.1 to 5.4. The weights of one story assemblages for each sway limitation are plotted in Fig. 5.5.

The weights of level 2 and level 4 do not change for the range of sway limitation $\rho_L = 0.0015$ to 0.004 and 0.0025 to 0.004, respectively. This means that the member sizes of level 2 and level 4 are controlled by the plastic moment condition under factored gravity load. At level 6, 8 and 10, the weights of each story assemblage increases gradually as the working load sway limitation decreases from 0.004 to about 0.0025 and then increases sharply for sway limitations less than about 0.0025. Figure 5.5 shows that for equal working load sways, the frame at level 6, 8 and 10 is up to 5.0 percent lighter than the frame obtained by the moment balancing method. For the sway limitation of about 0.002 at working loads, the optimum frame is somewhat heavier than the moment balancing frame as would be expected.

Figure 5.5 indicates that the gravity load condition controls the design of levels 2 and 4, as expected. However, the sway subassemblage method is not expected to yield accurate solutions in the top stories of a frame.[6] Therefore, minimum weight solution at levels 2 and 4 are somewhat questionable.

Figure 5.6 shows the horizontal force versus sway deflection behavior of level 8 of the minimum weight design under the working load value. The deflection indexes under the working load must be equal to the given sway limitation. The deflection indexes for $\rho_L = 0.0025$ and 0.003 are less than the given sway limitation because the combination of the beam and the column selected in a sway subassemblage is always equal to or larger than the value required. The deflection index for $\rho_L = 0.004$ is much less than the working load sway limitation because the member sizes of this one story assemblage were determined by the plastic moment condition. It is also clear from this that the plastic hinges form just after the attainment of the working load level of the horizontal force. Figure 5.7 and 5.8 show the horizontal force versus sway deflection behavior under the factored gravity load for level 6 and 8 of the minimum weight design frames. In level 6 and 8, all one story assemblages for sway limitations 0.001 to 0.003 have enough strength under the factored gravity load. However, the strength of levels 6 and 8 for sway limitation $\rho_L = 0.004$ is less than the factored load level.

From the view point of strength and economy, the sway limitation of $0.0025 \sim 0.003$ is available as far as Frame B is concerned.

6. CONCLUSIONS

A computer program has been developed for the minimum weight design of unbraced multi-story frames. The theoretical basis of program is the sway subassemblage method of analysis. The program is limited to rigid plane frames of up to thirty stories and five bays. Uniformly distributed girder loads and equal story heights are also assumed.

The calculation results were compared to Frame B from the Lehigh Summer Conference notes against the weight, strength and stiffness.

The weights of one story assemblages in level 8 and 10 decrease 3.5% and 5% against Frame B, respectively.

Further improvements of the program would be: 1) to use mixed yield stress level for beams and columns; 2) to restrict member sizes for the convenience of construction; and 3) to extend the program to apply to any arbitrary gravity loads on the beams as well as to uniformly distributed loads.

The frame designed by this computer program must be checked with respect to strength and stiffness using the sway subassemblage method of analysis.

7. NOMENCLATURE

E	=	Modulus of elasticity
h	=	story height
I	=	Moment of inertia
K	=	Restraint coefficient
L	=	Span length
P	=	Axial force
Q	=	Horizontal force
λ	=	Shear distribution factor
Δ	=	Sway deflection of one story assemblage
Δ_L	=	Working load sway limitations
ρ	=	Δ/h Deflection index
ρ_L	=	Δ_L/h

8. APPENDIX I

DERIVATION OF THE RELATIONSHIP BETWEEN THE HORIZONTAL SHEAR FORCE AND SWAY DEFLECTION (Eq. 3.1)

Reference will be made to Fig. 3.2 throughout the derivation of Equation 1.

Using the slope deflection equations, equilibrium of moments at joint i is given by

$$4E\,\frac{I_{i-1,i}}{L_{i-1,i}}\,\xi_{i-1} + \frac{I_{ij}}{L_{ij}}\,\xi_{i+1} + \frac{I_i}{h}\,U_i\,\theta_i - 4E\,\frac{I_i}{h}\,\rho\,U_i = 0$$

where
$$\xi_{i-1} = \frac{3 - K_{i-1,i}}{4 - K_{i-1,i}}$$

$$\xi_{i+1} = \frac{3 - K_{ij}}{4 - K_{ij}}$$

$$U_i = \frac{1}{C_i}\,(C_i^{\,2} - S_i^{\,2})$$

$$C_i = \frac{c_i}{c_i^{\,2} - s_i^{\,2}}$$

$$S_i = \frac{s_i}{c_i^{\,2} - s_i^{\,2}}$$

$$c_i = \frac{1}{\phi^2}\,(\phi \coth \phi - 1)$$

$$s_i = \frac{1}{\phi^2}\,\left(1 - \frac{\phi}{\text{smh}\,\phi}\right)$$

$$\phi = \frac{h}{2}\sqrt{\frac{P_i}{EI_i}}$$

The equilibrium shear force in the sway subassemblage is given by

$$\frac{h}{2}\lambda Q_n + \frac{1}{2}P\Delta = -2E\frac{I_i}{h}U_i\ (\theta_i - P)$$

Eliminating θ_i, equation 1 is obtained.

9. APPENDIX II

Program Printout
Program Nomenclature

$$


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      PROGRAM FRAMES(OUTPUT,TAPE 6=OUTPUT,INPUT,TAPE 5=INPUT)
      DIMENSION SPC(6,200), SPB(6,200)
      DIMENSION CLM(2,6,30), BEM(2,5,30)
      DIMENSION XL(5)
      DIMENSION P(6), W(5)
      DIMENSION CI1(6), BI1(5)
      DIMENSION DC(6), DB(5)
      DIMENSION NCI(6), NBI(5), NCI1(6), NBI1(5)
      DIMENSION BML(5), BMC(5), BMR(5), CM(6)
      DIMENSION SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      DIMENSION  U(6), D(6)
      DIMENSION  CI(6), BI(5), BIL(6), BIR(6)
      DIMENSION WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      DIMENSION WETB(30), WETC(30), WETB1(30), WETC1(30)
      DIMENSION WLD(30)
      DIMENSION RON(30)
      DIMENSION CF1(5), CF2(5), FLOAD(7), COEF(7,7), Q1(7), Q2(7,1)
      DIMENSION WS(5,200), WS1(6), WS3(7,7)
      DIMENSION XKL1(5), XKR1(5)
      DIMENSION A(6)
      DIMENSION CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      DIMENSION AX(5,30)
      DIMENSION NCI2(6), NBI2(5)
      DIMENSION BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      DIMENSION RON1(30)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC, SPB
      COMMON CLM, BEM
      COMMON H, XL
      COMMON P, W, Q
      COMMON CI1, BI1
      COMMON DC, DB
      COMMON NCI, NBI, NCI1, NBI1
      COMMON BML, BMC, BMR, CM
      COMMON SPL, SPR, PSL, PSR, XKL, XKR
      COMMON U, D
      COMMON CI, BI, BIL, BIR
      COMMON WLDC, WLDC1, WLDC2
      COMMON WETB, WETC, WETB1, WETC1
      COMMON WLD
      COMMON RON
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A
      COMMON ROX, RO0, RO
      COMMON CMOM, BMOMR, BMOML, BMOMC
      COMMON AX
      COMMON KK
      COMMON NCI2, NBI2
      COMMON BMI, CMI, ZB, ZC
      COMMON NOTR, IND
      COMMON RON1
C
C     SPC(I,J)=SECTION PROPERTIES OF AMERICAN STANDARD SHAPES FOR COLUMN
C     SPB(I,J)=SECTION PROPERTIES OF AMERICAN STANDARD SHAPES FOR BEAM
C     I=1 SECTION NUMBER AND NOMINAL SIZE
```

```
C       I=2 WEIGHT PER FOOT
C       I=3 AREA
C       I=4 MOMENT INERTIA
C       I=5 DEPTH
C       I=6 PLASTIC MODULUS
C       CLM(I,J,K)=COLUMN MEMBERS OF FRAME
C       BEM(I,J,K)=BEAM MEMBERS OF FRAME
C       I=1 SECTION NUMBER AND NOMINAL SIZE
C       I=2 WEIGHT PER FOOT
C       J=NO. OF COLUMN OR BAY
C       K=NO. OF STORY
C       XL(I)=SPAN LENGTH OF I-TH BAY
C       P(I)=AXTIAL THRUST OF I-TH COLUMN
C       W(I)=GRAVITY LOAD IN I-TH BEAM
C       CI(I), CI1(I), CI2(I)=MOMENT INERTIA OF I-TH COLUMN
C       BI(I), BI1(I), BI2(I)=MOMENT INERTIA OF I-TH BEAM
C       DC(I)=DEPTH OF I-TH COLUMN
C       DB(I)=DEPTH OF I-TH BEAM
C       BML(I)=BENDING MOMENT OF I-TH BEAM AT THE LEFT END
C       BMC(I)=BENDING MOMENT OF I-TH BEAM AT THE MIDDLE POINT
C       BMR(I)=BENDING MOMENT OF I-TH BEAM AT THE RIGHT END
C       CM(I)=BENDING MOMENT OF I-TH COLUMN
C       SPR(I)=THE RIGHT SIDE SPAN LENGTH OF I-TH COLUMN
C       SPL(I)=THE LEFT SIDE SPAN LENGTH OF I-TH COLUMN
C       PSR(I)=RESTRAINT FACTOR OF THE RIGHT SIDE OF I-TH COLUMN
C       PSL(I)=RESTRAINT FACTOR OF THE LEFT SIDE OF I-TH COLUMN
C       XKL(I)=RESTRAINT COEFFICIENT AT THE LEFT SIDE OF BEAM
C       XKR(I)=RESTRAINT COEFFICIENT AT THE RIGHT SIDE OF BEAM
C       XKR1(I)=RESTRAINT COEFFICIENT AT THE RIGHT SIDE OF BEAM
C       XKL1(I)=RESTRAINT COEFFICIENT AT THE LEFT SIDE OF BEAM
C       U(I)=REDUCTION COEFFICIENT OF THE STIFFNESS DUE TO AXIAL THRUST IN
C       I-TH COLUMN
C       D(I)=DISTRIBUTION FACTOR OF THE HORIZONTAL SHEAR FORCE IN I-TH
C       BIL(I)=MOMENT INERTIA OF LEFT SIDE BEAM OF I-TH COLUMN
C       BIR(I)=MOMENT INERTIA OF RIGHT SIDE BEAM OF I-TH COLUMN
C       WLDC(I,J)=AXIAL THRUST IN I-TH COLUMN AND J-TH LEVEL DUE TO
C       GRAVITY LOAD BASED ON TRIBUTARY AREA OF FLOORS
C       WLDC1(I,J)=AXIAL THRUST IN I-TH COLUMN AND J-TH LEVEL DUE TO WIND
C       LOAD
C       WLDC2(I)=AXIAL THRUST IN I-TH COLUMN AND J-TH LEVEL DUE TO
C       COMBINED LOAD
C       NBI(I), NBI1(I)=NO. OF I-TH BEAM
C       NCI(I), NCI1(I)=NO. OF I-TH COLUMN
C       WETB(I)=TOTAL WEIGHT OF BEAMS IN I-TH LEVEL OF PRELIMINARY DESIGND
C       FRAME
C       WETC(I)=TOTAL WEIGHT OF COLUMNS IN I-TH LEVEL OF PRELIMINARY
C       DESIGNED FRAME
C       WETB1(I)=TOTAL WEIGHT OF BEAMS IN I-TH LEVEL OF OPTIMUM DESIGNED
C       FRAME
C       WETC1(I)=TOTAL WEIGHT OF COLUMNS IN I-TH LEVEL OF OPTIMUM DESIGNED
C       FRAME
C       WLD(I)=WORKING WIND LOAD APPLIED AT I-TH LEVEL
C       RON SWA DEFLECTION ANGLE AT I-TH LEVEL DUE T/ WORKING WIND LOAD
C       CF1(I)=FIXED MOMENT AT THE RIGHT END OF I-TH BEAM
C       CFI(I)=FIXED MOMENT AT THE LEFT END OF I-TH BEAM
C       FLOAD(I)=LOADING TERMS OF SLOPE-DEFLECTION EQUATIONS
C       COEF(I,J)=COEFFICIENTS OF SLOPE-DEFLECTION EQUATIONS
C       Q1(I), Q2(I,1)=ROTATION ANGLE AT I-TH JOUNT
```

```
C       WS(I,J), WS1(I), WS3(I,J)=WORKING SPACES
C       A(I)=THE CHARACTORS INDICATED COLUMNS
C       CMOM(I,J)=BENDING MOMENT OF I-TH COLUMN IN LEVEL J
C       BMOMR(I,J)=BENDING MOMENT OF I-TH BEAM AT THE RIGHT END IN LEVEL J
C       BMOML(I,J)=BENDING MOMENT OF I-TH BEAM AT LEFT END IN LEVRL J
C       BMOMC(I,J)=BENDING MOMENT OF I-TH BEAM AT THE MIDDLE POINT IN
C       OF I-TH BEAM IN LEVEL L
C       AX(I,J)=THE LOCATION OF MAXIMUM BENDING MOMENT AT THE MIDDLE PIINT
C       OF I-TH BEAM IN LEVEL J
C       M=NUMBER OF STORIES
C       N=NUMBER OF BAYS
C       NN=N+1
C       NM=N+2
C       NC=NUMBER OF STANDARD SHAPES FOR COLUMN
C       NB=NUMBER OF STANDARD SHAPES FOR BEAM
C       H=STORY HEIGHT (IN INCH)
C       Q=HORIZONTAL SHEAR FORCE
C       SY=YIELD STRESS (I  KSI)
C       E=YOUNG≠S MODULUS (IN KSI)
        READ (5,102) (A(I), I=1,6)
    102 FORMAT (6A1)
        READ (5,101) M, N
    101 FORMAT (2I12)
        READ (5,104) H
    104 FORMAT (F12.0)
        READ (5,105) (XL(I), I=1,5)
    105 FORMAT (5F12.0)
        READ (5,105) (W(I), I=1,5)
        READ (5,106) E, SY
    106 FORMAT (2F12.0)
        NN=N+1
        NM=N+2
        IND=1
        CALL DATA1
        CALL DATA2
        CALL DATA3
        CALL WINDLD
        CALL ARRANG
        READ (5,103) ROX
    103 FORMAT (F12.0)
        IF (ROX.NE.0.0) GO TO 6
        RO=RO0
        GO TO 17
      6 RO=ROX
     17 DO 15 I=1,30
        DO 13 J=1,5
        BMI(J,I)=0.0
        ZB(J,I)=0.0
     13 CONTINUE
        DO 14 J=1,6
        CMI(J,I)=0.0
        ZC(J,I)=0.0
     14 CONTINUE
     15 CONTINUE
        DO 12 IND=1,2
        IF (IND.EQ.1) GO TO 1
        CALL WINDLD
        CALL TRANSP
```

```
    1 DO 5 M2=2, M, 2
      M1=M+2-M2
      WRITE (6,107) M1
  107 FORMAT (1H0,//, 10H LEVEL NO., I3, //)
      CALL DATA4
      KK=0
      DO 10 I=1, NN
      NCI1(I)=0
      NCI2(I)=0
   10 CONTINUE
      DO 11 I=1, N
      NBI1(I)=0
      NBI2(I)=0
   11 CONTINUE
      NOTR=1
    2 CALL COEFT(1)
      CALL DISFAC(1)
      IF (KK) 8, 9, 8
    9 CALL CHECK (JUDGE)
    8 DO 3 N1=1, N
      CALL MINWET
    3 CONTINUE
      CALL LASTCN
      KK=1
      CALL CHECK (JUDGE)
      IF (JUDGE) 2, 2, 4
    4 CALL RESULT
    5 CONTINUE
   16 IF (IND.EQ.1) GO TO 7
      CALL TRANSP
    7 CALL OUTPUT
   12 CONTINUE
      CALL EXIT
      END
```

```
      SUBROUTINE DATA1
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      READ (5,102) NC
  102 FORMAT (I12)
      DO 1 J=1,NC
      READ (5, 101) (SPC(I,J), I=1,6)
  101 FORMAT (A4, A5, F15.0, 3F12.0)
    1 CONTINUE
      READ (5,102) NB
      DO 2 J=1, NB
      READ (5,101) (SPB(I,J), I=1,6)
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DATA2
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      DO 1 I=1, M
      READ (5,102) ((BEM(J,K,I), J=1,2), K=1,5)
  102 FORMAT (5(A4, A6, 2X))
      READ (5,101) ((CLM(J,K,I), J=1,2), K=1,6)
  101 FORMAT (6(A4, A6, 2X))
    1 CONTINUE
      DO 5 K=1,M
      WETB1(K)=0.0
      DO 4 I=1, N
      DO 3 J=1, NB
      IF (BEM(1,I,K).NE.SPB(1,J)) GO TO 3
      IF (BEM(2,I,K).NE.SPB(2,J)) GO TO 3
      WETB1(K)=WETB1(K)+SPB(3,J)*XL(I)
      GO TO 4
    3 CONTINUE
    4 CONTINUE
      WETB1(K)=490.0*WETB1(K)/(12.0**3*2000.0)
    5 CONTINUE
      DO 8 K=1, M
      WETC1(K)=0.0
      DO 7 I=1, NN
      DO 6 J=1, NC
      IF (CLM(1,I,K).NE.SPC(1,J)) GO TO 6
      IF (CLM(2,I,K).NE.SPC(2,J)) GO TO 6
      WETC1(K)=WETC1(K)+SPC(3,J)*H
      GO TO 7
    6 CONTINUE
    7 CONTINUE
```

```
      WETC1(K)=490.0*WETC1(K)/(12.0**3*2000.0)
    8 CONTINUE
      TWETB=0.0
      DO 9 I=1, M
      TWETB=TWETB+WETB1(I)
    9 CONTINUE
      TWETC=0.0
      DO 10 I=1, M
      TWETC=TWETC+WETC1(I)
   10 CONTINUE
      TWET=TWETB+TWETC
      WRITE (6, 103)
  103 FORMAT (1H1, 20X, 62H***MEMBER SIZES OF FRAME DESIGNED BY MOMENT B
     1LANCING METHOD***)
      WRITE (6,107)
  107 FORMAT (1H0, 105X, 13HWEIGHT (TONS), ///)
      DO 2 I=1, M
      WRITE (6,105) I, ((BEM(J,K,I), J=1,2), K=1,5), WETB1(I)
  105 FORMAT (1H , I3, 5X, 5(5H*****, A4,A5,2H**), 1H*, 12X, F15.5)
      WRITE (6,108)
  108 FORMAT (1H , 8X, 6(1H*, 15X))
      WRITE (6,108)
      WRITE (6,104) ((CLM(J,K,I), J=1,2), K=1,6), WETC1(I)
  104 FORMAT (1H , 5X, 6(A4, A5,  7X), F15.5)
      WRITE (6,108)
      WRITE (6,108)
    2 CONTINUE
      WRITE (6,108)
      WRITE (6,109)
  109 FORMAT (5X, 89H***************************************************
     1**************************************,///)
      WRITE (6,106) TWETB, TWETC, TWET
  106 FORMAT (1H0, 21HTOTAL WEIGHT OF BEAMS,  80X, F15.5/24H TOTAL WEIGH
     1T OF COLUMNS, 78X, F15.5/22H TOTAL WEIGHT OF FRAME,  80X, F15.5)
      RETURN
      END
```

```
      SUBROUTINE DATA3
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      READ (5,101) ((WLDC(I,J), I=1,6), J=1,M)
  101 FORMAT (6F12.0)
      WRITE (6,102)
  102 FORMAT (1H1, 10X, 73H***GRAVITY LOADS IN COLUMNS OF FRAME BASED ON
     1 TRIBUTARY AREA OF FLOORS***)
      WRITE (6,104) (A(I),I=1, 6)
  104 FORMAT (1H0, 6(4X, 4HCOL., A1, 1X, 4HW.L., 4X),2X, 10HALL. COLS.)
      DO 1 J=1,M
      TWLDC=0.0
      DO 2 I=1,NN
    2 TWLDC=TWLDC+WLDC(I,J)
      JJ=J+1
      WRITE (6,103) (A(I), J, A(I),  JJ, WLDC(I,J), I=1, 6), TWLDC
  103 FORMAT (1H0, 6(A1, I2, 1H-, A1, I2, F 9.3, 2X), F12.5)
    1 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WINDLD
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      IF (IND.EQ.2) GO TO 17
      READ (5, 101) (WLD(I), I=1, M)
  101 FORMAT (6F12.0)
      DO 1 I=1, M
      DO 1 J=1, NN
      WLDC1(J,I)=0.0
    1 CONTINUE
      DO 6 M1=1, M
      CALL DATA4
      CALL COEFT (0)
      DO 2 I=1, NN
      IF (M1.EQ.1) GO TO 7
      P(I)=WLDC1(I,M1-1)+WLDC(I,M1)
      GO TO 2
    7 P(I)=WLDC(I,M1)
    2 CONTINUE
      CALL DISFAC (0)
      CALL MOM1
      RON (M1)=ROO
      DO 5 I=1, NN
      IF (I.NE.1) GO TO 3
      WLDC1(I, M1)=-(BMR(I)+BML (I))/XL(I)
      GO TO 8
    3 IF (I.NE.NN) GO TO 4
      WLDC1(I,M1)=(BMR(I-1)+BML (I-1))/XL(I-1)
      GO TO 8
    4 WLDC1(I, M1)=(BMR(I-1)+BML (I-1))/XL(I-1)-(BMR(I)+BML (I))/XL(I)
    8 IF (M1.EQ.1) GO TO 5
```

```
      WLDC1(I,M1)=WLDC1(I,M1)+WLDC1(I,M1-1)
    5 CONTINUE
      DO 16 J=NM, 6
      WLDC1(J,M1)=0.0
      WLDC2(J,M1)=0.0
   16 CONTINUE
    6 CONTINUE
      WRITE (6, 102)
  102 FORMAT (1H1, 30X, 66H***AXIAL COMPRESSIVE FORCE IN COLOMNS OF FRAM
     1E DUE TO WIND LOAD***,///)
      WRITE (6, 103) (A(I), I=1,  6)
  103 FORMAT (1H0, 6(1X, 4HCOL., A1, 1X, 9HWIND LOAD, 2X), 5X,  4HSWAY)
      DO 11 J=1, M
      JJ=J+1
      WRITE (6, 104) (A(I), J, A(I),  JJ, WLDC1(I,J), I=1,  6), RON (J)
  104 FORMAT (1H0, 6(A1, I2, 1H-, A1, I2, F 9.3, 2X), F12.5)
   11 CONTINUE
      ROO=0.0
      DO 14 I=1, M
      ROO=ROO+RON (I)
      RON1(I)=RON(I)
   14 CONTINUE
      ROO=ROO/FLOAT(M)
      DO 13 I=1, M
      DO 12 J=1, NN
   18 WLDC2(J,I)=WLDC(J,I)+WLDC1(J,I)
   12 CONTINUE
   13 CONTINUE
   17 IF (IND.EQ.1)  GOTO 21
      DO 19 I=1,M
      DO 20 J=1,NN
      WLDC2(J,I)=WLDC(J,I)-WLDC1(J,I)
   20 CONTINUE
   19 CONTINUE
   21 CONTINUE
      WRITE (6, 105)
  105 FORMAT (1H1, 30X, 59H***COMBINED AXIAL COMPRESSIVE FORCE IN COLUMN
     1S OF FRAMES***,)
      IF (IND.EQ.1) GO TO 22
      WRITE (6,108)
  108 FORMAT (1H , 51X, 17H(WIND FROM RIGHT))
      GO TO 23
   22 WRITE (6,109)
  109 FORMAT (1H , 52X, 16H(WIND FROM LEFT))
   23 CONTINUE
      WRITE (6, 106) (A(I), I=1,  6)
  106 FORMAT (1H0, 6(1X, 4HCOL., A1, 2X, 10HCOMB. LOAD), 2X, 10HWIND FOR
     1CE)
      DO 15 J=1, M
      JJ=J+1
      WRITE (6, 104) (A(I), J, A(I),  JJ, WLDC2(I,J), I=1, 6), WLD(J)
   15 CONTINUE
      WRITE (6,107)
  107 FORMAT (1H1)
      RETURN
      END
```

```
      SUBROUTINE ARRANG
      DIMENSION WS(6,200)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON U(6), D(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WLD(30)
      COMMON SY, E
      COMMON RON(30)
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      DO 204 J=1,NB
      XI=0.0
      DO 202 I=1,NB
      IF (SPB(4,I)-XI) 202, 201, 201
  201 XI=SPB(4,I)
      K=I
  202 CONTINUE
      DO 203 L=1,6
  203 WS(L,J)=SPB(L,K)
      SPB(4,K)=0.0
  204 CONTINUE
      DO 205 I=1,NB
      DO 205 J=1,6
  205 SPB(J,I)=WS(J,I)
      DO 209 J=1,NC
      XI=0.0
      DO 207 I=1,NC
      IF (SPC(4,I)-XI) 207, 206, 206
  206 XI=SPC(4,I)
      K=I
  207 CONTINUE
      DO 208 L=1,6
  208 WS(L,J)=SPC(L,K)
      SPC(4,K)=0.0
  209 CONTINUE
      DO 210 I=1,NC
      DO 210 J=1,6
```

```
210 SPC(J,I)=WS(J,I)
    RETURN
    END
```

```
      SUBROUTINE DATA4
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      Q=WLD(M1)
      DO 1 I=1, NN
    1 P(I)=WLDC2(I,M1)
      DO 3 I=1, NN
      DO 2 J=1, NC
      IF (CLM(1,I,M1).NE.SPC(1,J)) GO TO 2
      IF (CLM(2,I,M1).NE.SPC(2,J)) GO TO 2
      NCI(I)=J
      CI(I)=SPC(4,J)
      DC(I)=SPC(5,J)
      GO TO 3
    2 CONTINUE
    3 CONTINUE
      DO 5 I=1, N
      DO 4 J=1, NB
      IF (BEM(1,I,M1).NE.SPB(1,J)) GO TO 4
      IF (BEM(2,I,M1).NE.SPB(2,J)) GO TO 4
      NBI(I)=J
      BI(I)=SPB(4,J)
      DB(I)=SPB(5,J)
      GO TO 5
    4 CONTINUE
    5 CONTINUE
      DO 6 I=1, NN
      NCI1(I)= NCI(I)
    6 CI1(I)=CI(I)
      DO 7 I=1, N
      NBI1(I)=NBI(I)
```

```
7 BI1(I)=BI(I)
  RETURN
  END
```

```
      SUBROUTINE COEFT (L)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
  301 DO 314 I=1, NN
      IF (I-1) 303, 302, 303
  302 BIL(I)=0.0
      SPL(I)=1.0
      GO TO 305
  303 IF (I-N-1) 305, 304, 305
  304 BIR(I)=0.0
      SPR(I)=1.0
      GO TO 306
  305 BIR(I)=BI(I)
      SPR(I)=XL(I)
      IF (I-1) 306, 314, 306
  306 BIL(I)=BI(I-1)
      SPL(I)=XL(I-1)
  314 CONTINUE
      IF (L.EQ.0) GO TO 315
  307 CALL RESTRN
      DO 313 I=1, NN
      IF (I-1) 309, 308, 309
  308 PSL(I)=0.0
      GO TO 311
  309 IF (I-N-1) 311, 310, 311
  310 PSR(I)=0.0
      GO TO 312
  311 PSR(I)=(3.0-XKR(I))/(4.0-XKR(I))
      IF (I-1) 312, 313, 312
  312 PSL(I)=(3.0-XKL(I-1))/(4.0-XKL(I-1))
  313 CONTINUE
```

```
315 RETURN
    END
```

```
      SUBROUTINE RESTRN
      DIMENSION WS1(6), XKL1(5), XKR1(5)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      J=0
  401 XK1=0.0
      DO 402 I=1,N
      AL1=H*BIL(I)/(SPL(I)*CI(I))
      AL=H*BIR(I)/(SPR(I)*CI(I))
      BE=H*BIR(I)/(SPR(I)*CI(I+1))
      YE=H*BIR(I+1)/(SPR(I+1)*CI(I+1))
      IF (I+3.LE.NN) GO TO 20
      XSI=0.0
      IF (I+2.LE.NN) GO TO 18
      TAU=0.0
      GO TO 19
   20 XSI=H*BIR(I+2)/(SPR(I+2)*CI(I+2))
   18 TAU=H*BIR(I+1)/(SPR(I+1)*CI(I+2))
   19 XKL(I)=6.0*(3.0+BE*(6.0+2.0*TAU+3.0*XSI)/12.0+YE*(6.0+2.0*TAU+4.0
     1*XSI)/12.0+1.5*XSI+TAU+AL1*XK1*(6.0-YE+2.0*TAU+3.0*XSI)/72.0)/(
     23.0-AL*(6.0-YE+2.0*TAU+3.0*XSI)/12.0+BE*(12.0+4.0*TAU+6.0*XSI)/1
     32.0+TAU+1.5*XSI+YE*(12.0+3.0*TAU+6.0*XSI)/12.0)
      XKR(I)=4.0*(XKL(I)-3.0)/(XKL(I)-4.0)
      XK1=XKR(I)
  402 CONTINUE
      DO 403 I=1, NN
  403 WS1(I)=CI(N+2-I)
      DO 404 I=1, NN
  404 CI(I)=WS1(I)
      DO 405 I=1, NN
  405 WS1(I)=BIR(N+2-I)
```

```
      DO 406 I=1, NN
  406 BIR(I)=WS1(I)
      DO 407 I=1, NN
  407 WS1(I)=BIL(N+2-I)
      DO 408 I=1, NN
  408 BIL(I)=WS1(I)
      DO 409 I=1, NN
  409 WS1(I)=SPL(N+2-I)
      DO 410 I=1, NN
  410 SPL(I)=WS1(I)
      DO 411 I=1, NN
  411 WS1(I)=SPR(N+2-I)
      DO 412 I=1, NN
  412 SPR(I)=WS1(I)
      IF (J) 416, 414, 416
  414 DO 415 I=1, N
      XKL1(I)=XKL(I)
      XKR1(I)=XKR(I)
  415 CONTINUE
      J=1
      GO TO 401
  416 DO 417 I=1, N
      XKL(I)=(XKR(N+1-I)+XKL1(I))/2.0
      XKR(I)=(XKL(N+1-I)+XKR1(I))/2.0
  417 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DISFAC (L)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      DO 501 I=1, NN
      PHI=0.5*H*SQRT(P(I)/(E*CI(I)))
      COTH=(EXP(PHI)+EXP(-PHI))/(EXP(PHI)-EXP(-PHI))
      SINH=(EXP(PHI)-EXP(-PHI))/2.0
      CC=(PHI*COTH-1.0)/PHI**2
      SS=(1.0-PHI/SINH)/PHI**2
      CO=CC/(CC**2-SS**2)
      SO=SS/(CC**2-SS**2)
      U(I)=(CO**2-SO**2)/CO
      IF (L.EQ.0) GO TO 501
      D(I)=((BIL(I)*PSL(I)/SPL(I)+BIR(I)*PSR(I)/SPR(I))*(4.0*E*CI(I)
     1*U(I)/H-P(I)*H)-U(I)*P(I)*CI(I))/((BIL(I)*PSL(I)/SPL(I)+BIR(I)
     2*PSR(I)/SPR(I)+CI(I)*U(I)/H)*H)
  501 CONTINUE
      IF (L.EQ.0) GO TO 504
      S=0.0
      DO 502 I=1, NN
  502 S=S+D(I)
      DO 503 I=1, NN
  503 D(I)=D(I)/S
  504 RETURN
      END
```

```
      SUBROUTINE MOMENT
      DIMENSION CF1(5), CF2(5), COEF(7,7), FLOAD(7), WS3(7,7), Q2(7,1),
     1Q1(7)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      DO 601 I=1,N
      CF1(I)=-W(I)*XL(I)**2/12.0
      CF2(I)=W(I)*XL(I)**2/12.0
  601 CONTINUE
      DO 602 I=1, NN
      DO 602 J=1,NN
  602 COEF(I,J)=0.0
      DO 607 I=1,NN
      IF (I-1) 604, 603, 604
  603 FLOAD(I)=-CF1(I)
      GO TO 607
  604 IF (I-N-1) 606, 605, 606
  605 FLOAD(I)=-CF2(I-1)
      GO TO 607
  606 FLOAD(I)=-(CF1(I)+CF2(I-1))
  607 CONTINUE
      DO 608 I=1, NN
  608 COEF(I,I)=4.0*E*(BIL(I)/SPL(I)+BIR(I)/SPR(I))+4.0*E*CI(I)*U(I)/H
      DO 609 I=1,N
      J=I+1
      COEF(I,J)=2.0*E*BIR(I)/SPR(I)
      COEF(J,I)=COEF(I,J)
  609 CONTINUE
      CALL INVERT (COEF, WS3, N+1, N+1)
      CALL MATMUL (WS3, FLOAD, Q2, N+1, N+1, 1)
      DO 610 I=1,NN
```

```
610 Q1(I)=Q2(I,1)
    DO 611 I=1,NN
611 CM (I)=U(I)*2.0*E*CI(I)*Q1(I)/H
    DO 612 I=1,N
    BML (I)=E*BI(I)*(2.0*Q1(I+1)+4.0*Q1(I))/XL(I)+CF1(I)
612 BMR(I)=E*BI(I)*(4.0*Q1(I+1)+2.0*Q1(I))/XL(I)+CF2(I)
    RETURN
    END
```

```
      SUBROUTINE MINWET
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, RO0, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      XBM1=1.7*W(N1)*XL(N1)**2/16.0
      IF (N1.EQ.1) GO TO 14
      XBM2=1.7*W(N1-1)*XL(N1-1)**2/16.0
      XCM1=(XBM2-XBM1)/2.0
      GO TO 15
   14 XCM1=-XBM1/2.0
   15 IF (N1.NE.1) GO TO 19
      RCM=0.5*ABS(BML(N1))
      GO TO 17
   19 RCM=0.5*ABS(BML(N1)+BMR(N1-1))
   17 NI1=NBI(N1)-10
    1 IF (NI1.LE.0) NI1=1
      NI2=NI1+20
      IF (NI2.GE.NB) NI2=NB
      IF (N1-N) 24, 6, 24
    6 BIMIN=SPR(N1)*H*(P(N1+1)*RO+D(N1+1)*Q)/(4.0*E*RO*PSL(N1+1))
   24 WET=1.0E+10
      II=0
      DO 812 I=NI1, NI2
      XBIR=SPB(4,I)
      IF (N1-N) 8, 7, 8
    7 IF (XBIR-BIMIN) 9, 9, 8
    9 IF (I.NE.NI1) GO TO 813
      GO TO 2
    8 IF (ABS(BML(N1)).GT.ABS(BMC(N1))) GO TO 11
      BM=ABS(BMC(N1))
      GO TO 12
   11 BM=ABS(BML(N1))
```

```
   12 XBM=SY*SPB(6,I)
      IF (XBIR.LT.BMI(N1,M1)) GO TO 812
      IF (SPB(6,I).LT.ZB(N1,M1)) GO TO 812
      IF (XBM.GE.BM) GO TO 10
      GO TO 812
   10 IF (XBM1.GE.XBM) GO TO 812
      IF (ABS(BMR(N1)).GT.XBM) GO TO 812
    3 SPC1=FIC(XBIR, N1)
      IF (SPC1.GT.0.0) GO TO 808
      IF (I.NE.NI1) GO TO 813
      GO TO 2
  808 DO 809 J=1, NC
      IF (SPC1-SPC(4,J)) 810, 810, 812
  810 XCM=1.18*(1.0-P(N1) /(SPC(3,J)*SY))*SY*SPC(6,J)
      XCM0=1.18*(1.0-1.7*WLDC(N1,M1)/(SPC(3,J)*SY))*SY*SPC(6,J)
      IF (RCM.GT.XCM) GO TO 809
      IF (ABS(CM(N1)).GE.XCM) GO TO 809
      IF (ABS(XCM1).GT.XCM0) GO TO 809
      IF (SPC(4,J).LT.CMI(N1,M1)) GO TO 809
      IF (SPC(6,J).LT.ZC(N1,M1)) GO TO 809
  811 IF (J.EQ.NC) GO TO 2
      WET1=SPB(3,I)*SPR(N1)+SPC(3,J)*H
   13 IF (WET-WET1)  809, 809, 4
    4 WET=WET1
      NCI(N1)=J
    5 NBI(N1)=I
      II=1
  809 CONTINUE
  812 CONTINUE
      IF (II) 813, 2, 813
    2 NI1=NI1-10
      GO TO 1
  813 NI=NCI(N1)
      CI(N1)=SPC(4, NI)
      NI=NBI(N1)
      BI(N1)=SPB(4, NI)
      BIR(N1)=BI(N1)
      I=N1+1
      BIL(I)=BI(N1)
  821 RETURN
      END
```

```
      SUBROUTINE LASTCN
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON  P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      RCM=0.5*ABS(BMR(N))
      WS4=FIC(0.0)
      WET=1.0E+10
      XCM1=(1.7*W(N)*XL(N)**2/16.0)/2.0
    4 DO 1 I=1, NC
      XCM=1.18*(1.0-P(NN)/(SPC(3,I)*SY))*SY*SPC(6,I)
      XCM0=1.18*(1.0-1.7*WLDC(NN,M1)/(SPC(3,I)*SY))*SY*SPC(6,I)
      IF (ABS(CM(NN)).GE.XCM) GO TO 1
      IF (RCM.GT.XCM) GO TO 1
      IF (XCM1.GT.XCM0) GO TO 1
      IF (SPC(4,I).LT.CMI(NN,M1)) GO TO 1
      IF (SPC(6,I).LT.ZC(NN,M1)) GO TO 1
      IF (WS4-SPC(4,I)) 5, 5, 7
    5 WET1=SPC(3,I)
      IF (WET1-WET) 6, 6, 1
    6 WET=WET1
    2 NCI(NN)=I
      CI(NN)=SPC(4,I)
    1 CONTINUE
    7 RETURN
      END
```

```
      SUBROUTINE CHECK (JUDGE)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      IF (KK) 1, 2, 1
    1 WRITE (6,105) NOTR
  105 FORMAT (1H0, ///, 13H NO. OF TRIAL, I5)
      WRITE (6,908) (NBI(I), I=1,3)
      WRITE (6,909) (NCI(I),I=1,4)
  909 FORMAT (4I15)
  908 FORMAT (3I15)
      KKK=0
      DO 901 I=1, N
      IF (NBI1(I).NE.NBI(I)) GO TO 8
  901 CONTINUE
      DO 902 I=1, NN
      IF (NCI1(I).NE.NCI(I)) GO TO 8
  902 CONTINUE
      KKK=1
      GO TO 2
    8 DO 9 I=1, N
      IF (NBI2(I).NE.NBI(I)) GO TO 2
    9 CONTINUE
      DO 24 I=1, NN
      IF (NCI2(I).NE.NCI(I)) GO TO 2
   24 CONTINUE
      WETP1=0.0
      WETP2=0.0
      DO 25 I=1, N
      NI=NBI1(I)
      WETP1=WETP1+XL(I)*SPB(3,NI)
      NI=NBI2(I)
```

```
      WETP2=WETP2+XL(I)*SPB(3,NI)
   25 CONTINUE
      DO 26 I=1, NN
      NI=NCI1(I)
      WETP1=WETP1+H*SPC(3, NI)
      NI=NCI2(I)
      WETP2=WETP2+H*SPC(3,NI)
   26 CONTINUE
      IF (WETP2.GE.WETP1) GO TO 903
      DO 27 I=1, N
      NBI(I)=NBI1(I)
   27 CONTINUE
      DO 28 I=1, NN
      NCI(I)=NCI1(I)
   28 CONTINUE
      GO TO 903
    2 CALL MOMENT
      WRITE (6,109)
  109 FORMAT (1H0, 34HBENDING MOMENT DUE TO GRAVITY LOAD)
      WRITE (6,101) (CM(I), I=1,NN)
      WRITE (6,102) (BMR(I), I=1,N)
      WRITE (6,103) (BML(I), I=1,N)
      DO 10 I=1,NN
      CMOM(I,M1)=CM(I)
   10 CONTINUE
      DO 11 I=1,N
      BMOMR(I,M1)=BMR(I)
      BMOML(I,M1)=BML(I)
   11 CONTINUE
      CALL MOM1
      WRITE (6,106)
  106 FORMAT (1H0, 31HBENDING MOMENT DUE TO WIND LOAD)
      WRITE (6,101) (CM(I), I=1,NN)
      WRITE (6,102) (BMR(I), I=1,N)
      WRITE (6,103) (BML(I), I=1,N)
      WRITE (6,104) ROO
  101 FORMAT (1H , 26HBENDING MOMENTS IN COLUMNS, 25X, 6F12.5)
  102 FORMAT (1H , 41HBENDING MOMENTS AT LEE WARD ENDS OF BEAMS, 10X,
     15F12.5)
  103 FORMAT (1H , 42HBENDING MOMENTS AT WIND WARD ENDS OF BEAMS, 9X,
     15F12.5)
  104 FORMAT (1H , 45HTHE RATIO OF SWAY DEFLECTION AND STORY HEIGHT, 6X,
     1F12.5)
      DO 12 I=1,NN
      CMOM(I,M1)=CMOM(I,M1)+CM(I)
      CM(I)=CMOM(I,M1)
   12 CONTINUE
      DO 13 I=1,N
      BMOMR(I,M1)=BMR(I)+BMOMR(I,M1)
      BMOML(I,M1)=BML(I)+BMOML(I,M1)
      BMR(I)=BMOMR(I,M1)
      BML(I)=BMOML(I,M1)
   13 CONTINUE
      DO 16 I=1,N
      AX(I,M1)=0.5-(BMOMR(I,M1)+BMOML(I,M1))/(W(I)*XL(I)**2)
      IF (AX(I,M1)) 14, 14, 15
   14 AX(I,M1)=0.0
      BMOMC(I,M1)=BMOML(I,M1)
```

```
      GO TO 5
   15 BMOMC(I,M1)=BMOML(I,M1)-(BMOML(I,M1)+BMOMR(I,M1))*AX(I,M1)+W(I)*
     1XL(I)**2*(AX(I,M1)-AX(I,M1)**2)/2.0
    5 BMC(I)=BMOMC(I,M1)
   16 CONTINUE
      DO 17 I=1,NN
      NI=NCI(I)
      PM=1.18*(1.0-P(I)/(SPC(3,NI)*SY))*SY*SPC(6,NI)
      CMOM(I,M1)=CMOM(I,M1)/PM
   17 CONTINUE
      DO 18 I=1,N
      NI=NBI(I)
      PM=SY*SPB(6,NI)
      BMOMR(I,M1)=BMOMR(I,M1)/PM
      BMOML(I,M1)=BMOML(I,M1)/PM
      BMOMC(I,M1)=BMOMC(I,M1)/PM
   18 CONTINUE
      IF (KK) 3, 4, 3
    3 WRITE (6,107)
  107 FORMAT (1H0, 54HNON-DIMENSIONALIZED BENDING MOMENT UNDER COMBINED
     1LOAD)
      WRITE (6,101) (CMOM(I,M1), I=1,NN)
      WRITE (6,102) (BMOMR(I,M1), I=1,N)
      WRITE (6,103) (BMOML(I,M1), I=1,N)
      WRITE (6,108) (BMOMC(2,M1), I=1,N)
  108 FORMAT (1H , 38HBENDING MOMENT AT MIDDLE POINT IN BEAM,13X,5F12.5)
      IF (KKK.EQ.0) GO TO 904
      DO 21 I=1,NN
      IF (ABS(CMOM(I,M1)).GT.1.0) GO TO 23
   21 CONTINUE
      DO 22 I=1,N
      IF (ABS(BMOMR(I,M1)).GT.1.0) GO TO 23
      IF (ABS(BMOML(I,M1)).GT.1.0) GO TO 23
      IF (ABS(BMOMC(I,M1)).GT.1.0) GO TO 23
   22 CONTINUE
      GO TO 903
   23 RO=RO-0.0001
      GO TO 904
  903 JUDGE=1
      RETURN
  904 JUDGE=-1
      NOTR=NOTR+1
      DO 6 I=1, N
      NBI2(I)=NBI1(I)
    6 CONTINUE
      DO 7 I=1, NN
      NCI2(I)=NCI1(I)
    7 CONTINUE
      DO 905 I=1,N
      NI=NBI(I)
      NBI1(I)=NI
      DB(I)=SPB(5, NI)
  905 BI1(I)=BI(I)
      DO 906 I=1,NN
      NI=NCI(I)
      NCI1(I)=NI
      DC(I)=SPC(5, NI)
  906 CI1(I)=CI(I)
```

```
4 RETURN
  END
```

```
      SUBROUTINE RESULT
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      M11=M1-1
      WETC(M1)=0.0
      DO 2 I=1, NN
      NI=NCI(I)
      K=NN+1-I
      CMI(K,M1)=SPC(4,NI)
      ZC(K,M1)=SPC(6,NI)
      DO 1 J=1, 2
    1 CLM(J,I,M1)=SPC(J,NI)
      IF (M11) 5, 5, 11
   11 DO 6 J=1,2
    6 CLM(J,I,M11)=SPC(J,NI)
      CMI(K,M11)=CMI(K,M1)
      ZC(K,M11)=ZC(K,M1)
    5 WETC(M1)=WETC(M1)+SPC(3,NI)*H
    2 CONTINUE
      WETB(M1)=0.0
      DO 4 I=1, N
      NI=NBI(I)
      K=N+1-I
      BMI(K,M1)=SPB(4,NI)
      ZB(K,M1)=SPB(6,NI)
      DO 3 J=1, 2
    3 BEM(J,I,M1)=SPB(J,NI)
      IF (M11) 7, 7, 12
   12 DO 8 J=1,2
    8 BEM(J,I,M11)=SPB(J,NI)
      BMI(K,M11)=BMI(K,M1)
```

```
      ZB(K,M11)=ZB(K,M1)
    7 WETB(M1)=WETB(M1)+SPB(3,NI)*XL(I)
    4 CONTINUE
      WETC(M1)=490.0*WETC(M1)/(12.0**3*2000.0)
      WETB(M1)=490.0*WETB(M1)/(12.0**3*2000.0)
      RON(M1)=RO
      RO=ROX
      IF (M11) 9, 9, 10
   10 WETC(M11)=WETC(M1)
      WETB(M11)=WETB(M1)
      RON(M11)=RON(M1)
    9 RETURN
      END
```

```
      SUBROUTINE OUTPUT
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
    4 WRITE (6,101)
  101 FORMAT (1H1, 30X, 35H***OPTIMUM MEMBER SIZES OF FRAME***,/)
      IF (IND.EQ.1) GO TO 6
      WRITE (6,122)
  122 FORMAT (1H , 39X, 17H(WIND FROM RIGHT))
      GO TO 7
    6 WRITE (6,123)
  123 FORMAT (1H , 39X, 16H(WIND FROM LEFT))
    7 CONTINUE
      WRITE (6,112)
  112 FORMAT (1H0, 105X, 13HWEIGHT (TONS), ///)
      DO 1 I=1, M
      WRITE (6,102) I, ((BEM(J,K,I), J=1,2), K=1,5), WETB(I)
  102 FORMAT (1H , I3, 5X, 5(5H*****, A4, A5, 2H**), 1H*, 12X, F15.5)
      WRITE (6,113)
  113 FORMAT (1H , 8X, 6(1H*, 15X))
      WRITE (6,113)
  103 WRITE  (6,104) ((CLM(J,K,I), J=1,2), K=1,6), WETC(I)
  104 FORMAT (1H , 5X, 6(A4, A5,  7X), F15.5)
      WRITE (6,113)
      WRITE (6,113)
    1 CONTINUE
      WRITE (6,109)
  109 FORMAT (5X, 89H*****************************************************
     1*************************************, ///)
      TWETB=0.0
      TWETB1=0.0
      TWETC=0.0
```

```
      TWETC1=0.0
      DO 2 I=1, M
      TWETB=TWETB+WETB(I)
      TWETB1=TWETB1+WETB1(I)
      TWETC=TWETC+WETC(I)
      TWETC1=TWETC1+WETC1(I)
    2 CONTINUE
      RATIOB=TWETB/TWETB1
      RATIOC=TWETC/TWETC1
      RATIOD=TWETB1/TWETC1
      RATIOE=TWETB/TWETC
      TWET=TWETB+TWETC
      TWET1=TWETB1+TWETC1
      RATIO=TWET/TWET1
      WRITE (6, 106) TWETB, RATIOB, TWETC, RATIOC, TWET, RATIO
  106 FORMAT (1H0, 21HTOTAL WEIGHT OF BEAMS, 2X, F15.5, 5X, 1H(, F10.5,
     11H),/ 24H TOTAL WEIGHT OF COLUMNS, F15.5, 5X, 1H(, F10.5, 1H),/,
     2  22H TOTAL WEIGHT OF FRAME, 2X, F15.5, 5X, 1H(, F10.5, 1H),)
      WRITE (6,105)
  105 FORMAT (1H1, 10X, 89H***BENDING MOMENT AT BOTH ENDS AND MAXIMUM IN
     1TERIOR OF BEAMS AND AT THE TOP OF COLUMNS***,///)
      DO 3 I=1,M
      WRITE (6,108) (BMOML(J,I), BMOMR(J,I), J=1,5)
  108 FORMAT (1H , 3X, 1H*, 5(F7.4, 7H*******, F7.4, 1H*))
      WRITE (6,110) (BMOMC(J,I), J=1,5)
  110 FORMAT (1H , 3X, 1H*, 7X, 5(F7.4, 7X, 1H*, 7X))
      WRITE (6,114)
  114 FORMAT (1H , 3X, 1H*, 5(21X, 1H*))
      WRITE (6,111) (CMOM(J,I), J=1,6)
  111 FORMAT (1H , 5(F7.4,15X), F7.4/)
      WRITE (6,114)
      WRITE (6,114)
    3 CONTINUE
      WRITE (6,114)
      WRITE (6,121)
  121 FORMAT (1H , 11(10H**********), 7H*******)
      WRITE (6,115)
  115 FORMAT (1H1, 30X, 68HCOMPARISON BETWEEN PRELIMINARY DESIGN FRAME A
     1ND OPTIMUM DESIGN FRAME, ///)
      WRITE (6,117)
  117 FORMAT (1H0, 13X, 24HPRELIMINARY DESIGN FRAME, 13X, 15X, 20HOPTIMU
     1M DESIGN FRAME)
      WRITE (6,116)
  116 FORMAT (1H , 6HLEVEL*, 2(3X, 13HWEIGHT (TONS), 4X, 2X, 5HRATIO,
     13X, 2X, 5HTOTAL, 3X, 3X, 4HSWAY, 3X, 1H*), 2X, 5HRATIO)
      WRITE (6,118)
  118 FORMAT (1H , 5X, 1H*, 2(2X, 5HBEAMS, 3X, 1X, 7HCOLUMNS,12X, 2X,
     16HWEIGHT, 2X, 3X, 4HRO/H, 3X, 1H*))
      DO 5 I=1,M
      RATIO1=WETB1(I)/WETC1(I)
      RATIO2=WETB(I)/WETC(I)
      TWETP=WETB1(I)+WETC1(I)
      TWETO=WETB(I)+WETC(I)
      RATIO3=TWETO/TWETP
      WRITE (6,119) (I, WETB1(I), WETC1(I), RATIO1, TWETP, RON1(I),
     1WETB(I), WETC(I), RATIO2, TWETO, RON(I), RATIO3)
  119 FORMAT (1H0, I3, 2X, 1H*, 2(5F10.5, 1H*), F10.5)
    5 CONTINUE
```

```
      WRITE (6,120) (TWETB1, TWETC1, RATIOD, TWET1, TWETB, TWETC,
     1RATIOE, TWET)
  120 FORMAT (1H0, 6HTOTAL*, 2(4F10.5, 10X, 1H*))
      RETURN
      END
```

```
      FUNCTION FIB(XCI)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, RO0, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      FIB=(4.0*E*XCI*U(N1)*RO*BIL(N1)*PSL(N1)/(H*SPL(N1))-(D(N1)*H*Q+
     1P(N1)*H*RO)*BIL(N1)*PSL(N1)/SPL(N1)-(P(N1)*RO+D(N1)*Q)*U(N1)*XCI)*
     2SPR(N1) /((D(N1)*H*Q+P(N1)*H*RO-4.0*E*XCI*U(N1)*RO/H)*PSR(N1))
      RETURN
      END
```

```
      FUNCTION FIC(XBIR)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      FIC=(D(N1)*H*Q+RO*P(N1)*H)*(BIL(N1)*PSL(N1)/SPL(N1)+XBIR*PSR(N1)/
     1SPR(N1))*H/(4.0*E*U(N1)*RO*(BIL(N1)*PSL(N1)/SPL(N1)+XBIR*PSR(N1)
     2/SPR(N1))-U(N1)*P(N1)*H*RO-D(N1)*U(N1)*H*Q)
      RETURN
      END
```

```
      SUBROUTINE MOM1
      DIMENSION CF1(5), CF2(5), COEF(7,7), FLOAD(7), WS3(7,7), Q2(7,1),
     1Q1(7)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, ROO, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      DO 1 I=1, NM
      DO 1 J=1, NM
      COEF(I,J)=0.0
    1 CONTINUE
      DO 2 I=1, NN
      FLOAD(I)=0.0
    2 CONTINUE
      FLOAD(NM)=-Q*H/2.0
      IF (M1.EQ.1) GO TO 11
      G1=4.0
      GO TO 12
   11 G1=2.0
   12 DO 3 I=1, NN
      COEF(I,I)=4.0*E*(BIL(I)/SPL(I)+BIR(I)/SPR(I))+G1 *E*CI(I)*U(I)/H
    3 CONTINUE
      DO 4 I=1, N
      J=I+1
      COEF(I,J)=2.0*E*BIR(I)/SPR(I)
      COEF(J,I)=COEF(I,J)
    4 CONTINUE
      DO 5 I=1, NN
      COEF(I,NM)=-G1*E*CI(I)*U(I)/H
    5 CONTINUE
      DO 6 I=1, NN
      COEF(NM,I)=2.0*E*U(I)*CI(I)/H
    6 CONTINUE
```

```
      COEF(NM,NM)=0.0
      DO 7 I=1, NN
      COEF(NM,NM)=COEF(NM,NM)-COEF(NM,I)
    7 CONTINUE
      CALL INVERT (COEF, WS3, NM, NM)
      CALL MATMUL (WS3, FLOAD, Q2, NM, NM, 1)
      DO 8 I=1, NM
      Q1(I)=Q2(I,1)
    8 CONTINUE
      DO 9 I=1, NN
      CM (I)=2.0*U(I)*E*CI(I)*(Q1(I)-Q1(NM))/H
    9 CONTINUE
      DO 10 I=1, N
      BMR(I)=E*BI(I)*(4.0*Q1(I+1)+2.0*Q1(I))/XL(I)
      BML (I)=E*BI(I)*(4.0*Q1(I)+2.0*Q1(I+1))/XL(I)
   10 CONTINUE
      RO0=Q1(NM)
      RETURN
      END
```

```
      SUBROUTINE TRANSP
      DIMENSION WS1(6)
      COMMON M, N, M1, N1, NN, NM
      COMMON NC, NB
      COMMON SPC(6,200), SPB(6,200)
      COMMON CLM(2,6,30), BEM(2,5,30)
      COMMON H, XL(5)
      COMMON P(6), W(5), Q
      COMMON CI1(6), BI1(5)
      COMMON DC(6), DB(5)
      COMMON NCI(6), NBI(5), NCI1(6), NBI1(5)
      COMMON BML(5), BMC(5), BMR(5), CM(6)
      COMMON SPL(6), SPR(6), PSL(6), PSR(6), XKL(5), XKR(5)
      COMMON U(6), D(6)
      COMMON CI(6), BI(5), BIL(6), BIR(6)
      COMMON WLDC(6,30), WLDC1(6,30), WLDC2(6,30)
      COMMON WETB(30), WETC(30), WETB1(30), WETC1(30)
      COMMON WLD(30)
      COMMON RON(30)
      COMMON SY, E
      COMMON BILIM1, BILIM2, CILIM1, CILIM2
      COMMON A(6)
      COMMON ROX, RO0, RO
      COMMON CMOM(6,30), BMOMR(5,30), BMOML(5,30), BMOMC(5,30)
      COMMON AX(5,30)
      COMMON KK
      COMMON NCI2(6), NBI2(5)
      COMMON BMI(5,30), CMI(6,30), ZB(5,30), ZC(6,30)
      COMMON NOTR, IND
      COMMON RON1(30)
      DO 1 I=1,N
      WS1(I)=XL(N+1-I)
    1 CONTINUE
      DO 2 I=1,N
      XL(I)=WS1(I)
    2 CONTINUE
      DO 3 I=1,N
      WS1(I)=W(N+1-I)
    3 CONTINUE
      DO 4 I=1,N
      W(I)=WS1(I)
    4 CONTINUE
      DO 7 I=1,M
      DO 5 J=1,NN
      WS1(J)=WLDC2(NN+1-J,I)
    5 CONTINUE
      DO 6 J=1,NN
      WLDC2(J,I)=WS1(J)
    6 CONTINUE
    7 CONTINUE
    8 DO 12 I=1,M
      DO 11 K=1,2
      DO 9 J=1,NN
      WS1(J)=CLM(K,NN+1-J, I)
    9 CONTINUE
      DO 10 J=1,NN
      CLM(K,J,I)=WS1(J)
```

```
10 CONTINUE
11 CONTINUE
   DO 15 K=1,2
   DO 13 J=1,N
   WS1(J)=BEM(K,N+1-J,I)
13 CONTINUE
   DO 14 J=1,N
   BEM(K,J,I)=WS1(J)
14 CONTINUE
15 CONTINUE
   DO 18 J=1,N
   WS1(J)=BMOMR(N+1-J,I)
18 CONTINUE
   DO 19 J=1,N
   BMOMR(J,I)=WS1(J)
19 CONTINUE
   DO 20 J=1,N
   WS1(J)=BMOML(N+1-J,I)
20 CONTINUE
   DO 21 J=1,N
   BMOML(J,I)=WS1(J)
21 CONTINUE
   DO 22 J=1,N
   WS1(J)=BMOMC(N+1-J,I)
22 CONTINUE
   DO 23 J=1,N
   BMOMC(J,I)=WS1(J)
23 CONTINUE
   DO 24 J=1,NN
   WS1(J)=CMOM(NN+1-J,I)
24 CONTINUE
   DO 25 J=1,NN
   CMOM(J,I)=WS1(J)
25 CONTINUE
12 CONTINUE
17 RETURN
   END
```

```
      SUBROUTINE INVERT (A1, B1, L1, M1)
      DIMENSION A1(7,7), B1(7,7)
      DO 1001 K1=1, L1
      DO 1001 K2=1,M1
      B1(K1, K2)=0.0
 1001 B1(K1, K1)=1.0
      DETER=1.0
      DO 1006 N1=1, L1
      COEF1=A1(N1, N1)
      DETER=DETER*A1(N1, N1)
      IF (DETER) 1003, 1002, 1003
 1002 WRITE (10, 1100)
 1100 FORMAT (//, 25H THE DETERMINANT IS ZERO )
      RETURN
 1003 CONTINUE
C     MAKE THE DIAGONAL ELEMENTS = 1.0
      DO 1004 J1= 1, L1
      A1(N1, J1)=A1(N1, J1)/COEF1
      B1(N1, J1)=B1(N1, J1)/COEF1
 1004 CONTINUE
C     MAKE THE NON-DIAGONAL ELEMENTS = 0.0
      DO 1006 I1=1, M1
      IF (I1-N1) 1005, 1006, 1005
 1005 CONTINUE
      COEFF=A1(I1, N1)
      DO 1006 J1=1, L1
      A1(I1, J1)=A1(I1, J1)-COEFF*A1(N1, J1)
      B1(I1, J1)=B1(I1, J1)-COEFF*B1(N1, J1)
 1006 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MATMUL (A2, B2, Q2, K2, L2, M2)
      DIMENSION A2(7,7), B2(7,7), Q2(7,1)
      DO 1202 I2=1, K2
      DO 1202 N2= 1, M2
      Q2(I2, N2)=0.0
      DO 1201 J2=1, L2
      QQ=A2(I2, J2)*B2(J2, N2)
 1201 Q2(I2, N2)=Q2(I2, N2)+QQ
 1202 CONTINUE
      RETURN
      END
```

PROGRAM NOMENCLATURE

A	Indicator of Columns
AX	The distance from maximum bending moment point in beam to the left side of beam.
ARRANG	Name of subroutine subprogram
BEM	Name of shape in beam
BI	Moment of inertia of beam
BIL	Moment of inertia of left side beam of column
BIR	Moment of inertia of right side beam of column
BMC	Maximum bending moment in beam
BMI	Moment of inertia of beam in minimum weight design frame for wind from left.
BML	Bending moment at the left end of the beam
BMR	Bending moment at the right end of the beam
BMOMC	Non-dimensionalized maximum bending moment in beam by the full plastic moment.
BMOML	Non-dimensionalized bending moment at the left end of beam by the full plastic moment
BMOMR	Non-dimensionalized bending moment at the right end of beam by the full plastic moment
CF1	Fixed end moment at the right end of beam
CF2	Fixed end moment at the left end of beam
CI	Moment of inertia of column
CLM	Name of shape in column
CM	Bending moment in column at joint
CMI	Moment of inertia of column in minimum weight design frame for wind from right

CMOM	Non-dimensionalized bending moment in column at joint by the full plastic moment
COEF	Coefficients in the slope-deflection equation
D	Shear distribution factor
DB	Depth in beam
DC	Depth in column
E	Modulus of elasticity
FLOAD	Load term in the slope-deflection equation
H	Story height
IND	Indicator of wind direction
JUDGE	Judgement of convergency
M	Number of stories
N	Number of bays
NB	Number of shapes in beams
NC	Number of shapes in column
NBI	Location of shapes in beam in computer
NCI	Location of shapes in column in computer
P	Axial force in column
PSL	Restraint factor of the left end of beam
PSR	Restraint factor of the right end of beam
Q	Total shear force in one story assemblage
Q1	Joint rotation angle
RO	Sway limitation index
RON	Sway indexes in the beam designed by moment balancing method
RON1	Sway index in the minimum weight design frames
SPB	Sectional properties of beams
SPC	Sectional properties of columns

SPL	Span length of the left side beam of the column
SPR	Span length of the right side of beam of the column
SY	Yield stress level
TWLDC	Total axial force in columns of one story assemblage
TWET	Total weight of frame
TWETB	Total weight of beams in frame
TWETC	Total weight of columns in frame
U	Coefficient of columns in the slope-deflection equation
W	Uniformly distributed gravity load on beam
WETB	Weight of beams in one story assemblage of minimum weight design frame
WETB 1	Weight of beams in one story assemblage of frame designed by moment balancing method
WETC	Weight of columns in one story assemblage of minimum weight design frame
WETC 1	Weight of columns in one story assemblage of frame designed by moment balancing method
WLD	Working wind load
XKL	Restraining coefficient of the left side of column
XKR	Restraining coefficient of the right side of column
ZB	Plastic modulus of beams in minimum weight design frame for wind from left.
ZC	Plastic modulus of columns in minimum weight design frame for wind from left.

10. APPENDIX III

Input Format

INPUT FORMAT

Card No.	Data	Symbol	Format
1	Indicator of column	A(I)	6A1
2	Number of stories Number of bays	M, N	2I12
3	Story height (in.)	H	F12.0
4	Span lengths of bays (in.)	XL(I)	5F12.0
5	Working gravity loads on beams (kip/in.)	W(I)	5F12.0
5	Modulus of elasticity (kip/in^2) yield stress level (kip/in^2)	E, SY	2F12.0
6	Number of shapes for column	NC	I12
7*	Sectional properties of shape I = 1 Nominal size I = 2 Weight per foot I = 3 Sectional area ($in.^2$) I = 4 Moment of inertia (in^4) I = 5 Depth (in.) I = 6 Plastic modulus (in^3)	SPC(I,J)	A4, A5, F15.0,3F12.0
8	Number of shapes for beam	NB	I12
9**	Sectional properties of shape I = 1 Nominal size I = 2 Weight per foot I = 3 Sectional area (in^2) I = 4 Moment of inertia (in^4) I = 5 Depth (in.) I = 6 Plastic Modulus (in^3)	SPB(I,J)	A4, A5. F15.0,3F12.0
10***	Section names of beam for frame designed by moment balancing	BEM(J,K,I)	5(A4,A6,2X)
11***	Section names of column for frame designed by moment balancing	CLM(J,K,I)	6(A4,A6,2X)
12****	Gravity loads in columns of the frame based on tributary area of floor (kips)	WLDC(I,J)	6F12.0
13*****	Wind load (kips)	WLD(I)	6F12.0
14	Sway limitation	ROX	F12.0

* This and following data cards of number of NC are required.

** This and following data cards of number of NB are required

*** M sets of 10 and 11 cards are required. 10 and 11 cards must be arranged from level 1 to level M.

**** This and following data cards of number of M are required. 12 cards must be arranged from level 1 to level M.

***** This wind load is the total horizontal shear force for this story and upper story.

11. TABLES AND FIGURES

TABLE 2.1

Axial Forces in Columns due to the Working Wind Loads

(kips)

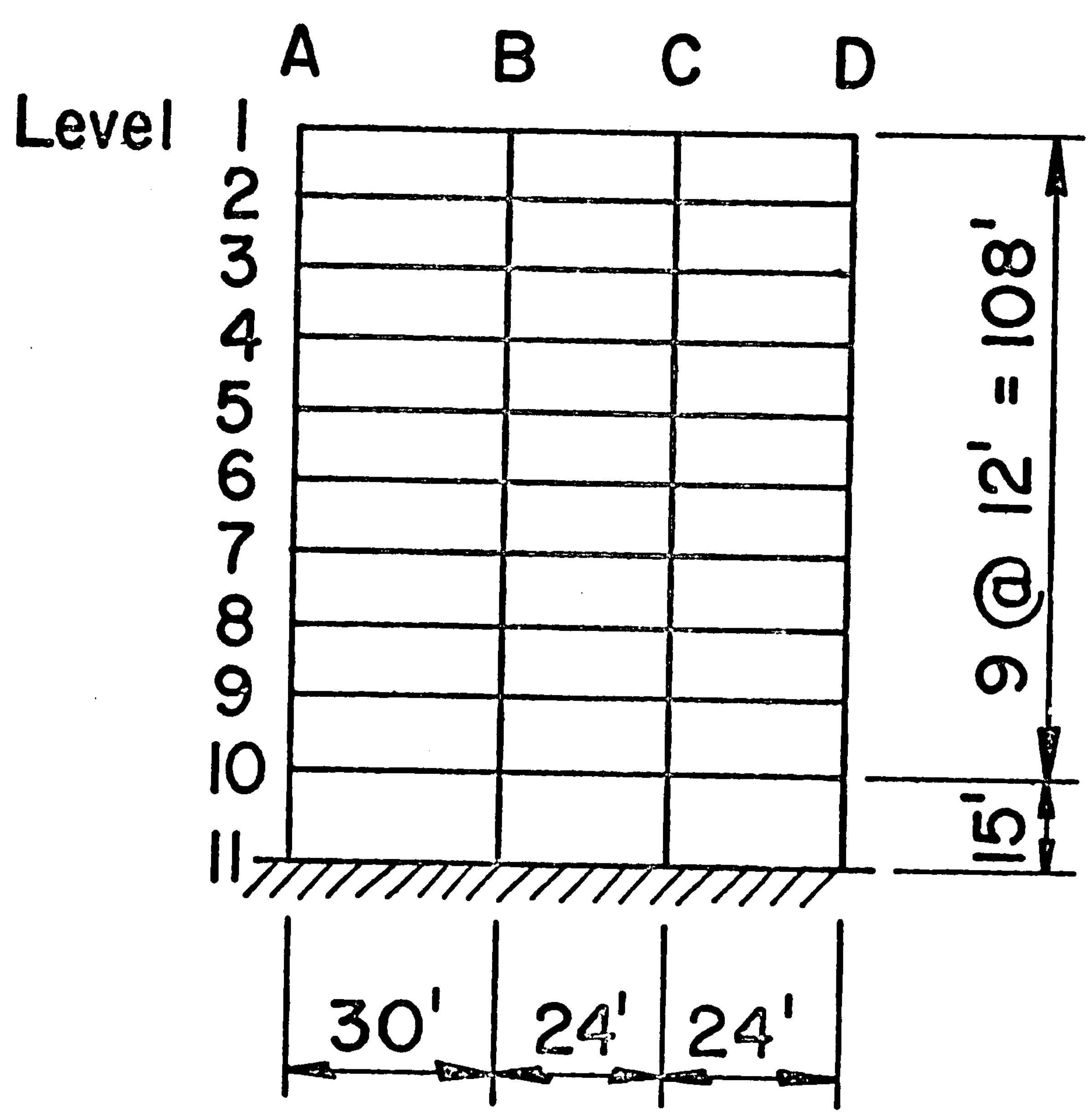
Level	A	B	C	D
1	-0.31	0.18	-0.07	0.20
2	-2.20	1.22	-0.33	1.31
3	-4.82	1.95	-0.46	3.33
4	-8.50	2.97	-0.65	6.17
5	-12.49	3.08	-0.84	10.25
6	-17.38	3.22	-1.08	15.24
7	-23.16	3.35	-1.27	21.08
8	-28.34	1.07	-1.46	28.73
9	-34.18	-1.44	-1.96	37.58
10	-40.76	-4.27	-2.54	47.57

TABLE 2.2

Axial Forces in Columns due to the Factored Wind Loads

(kips)

Level	A	B	C	D
1	-8.92	6.61	0	2.31
2	-17.75	9.93	0	7.82
3	-26.64	12.66	0	13.98
4	-35.53	15.39	0	20.14
5	-48.17	13.95	0	34.22
6	-60.86	12.51	0	48.30
7	-73.45	11.07	0	62.38
8	-89.74	-1.62	0	91.36
9	-110.42	-13.90	0	124.31
10	-131.09	-20.18	0	157.26



Bent Spacing = 24'

Working Loads:

Roof W_L = 30 psf

W_D = 60 psf

Floor W_L = 80 psf

W_D = 80 psf

Exterior Wall

W_D = 45 psf

Wind 20 psf

Fig. 2.1 Frame B: Geometry and Loading

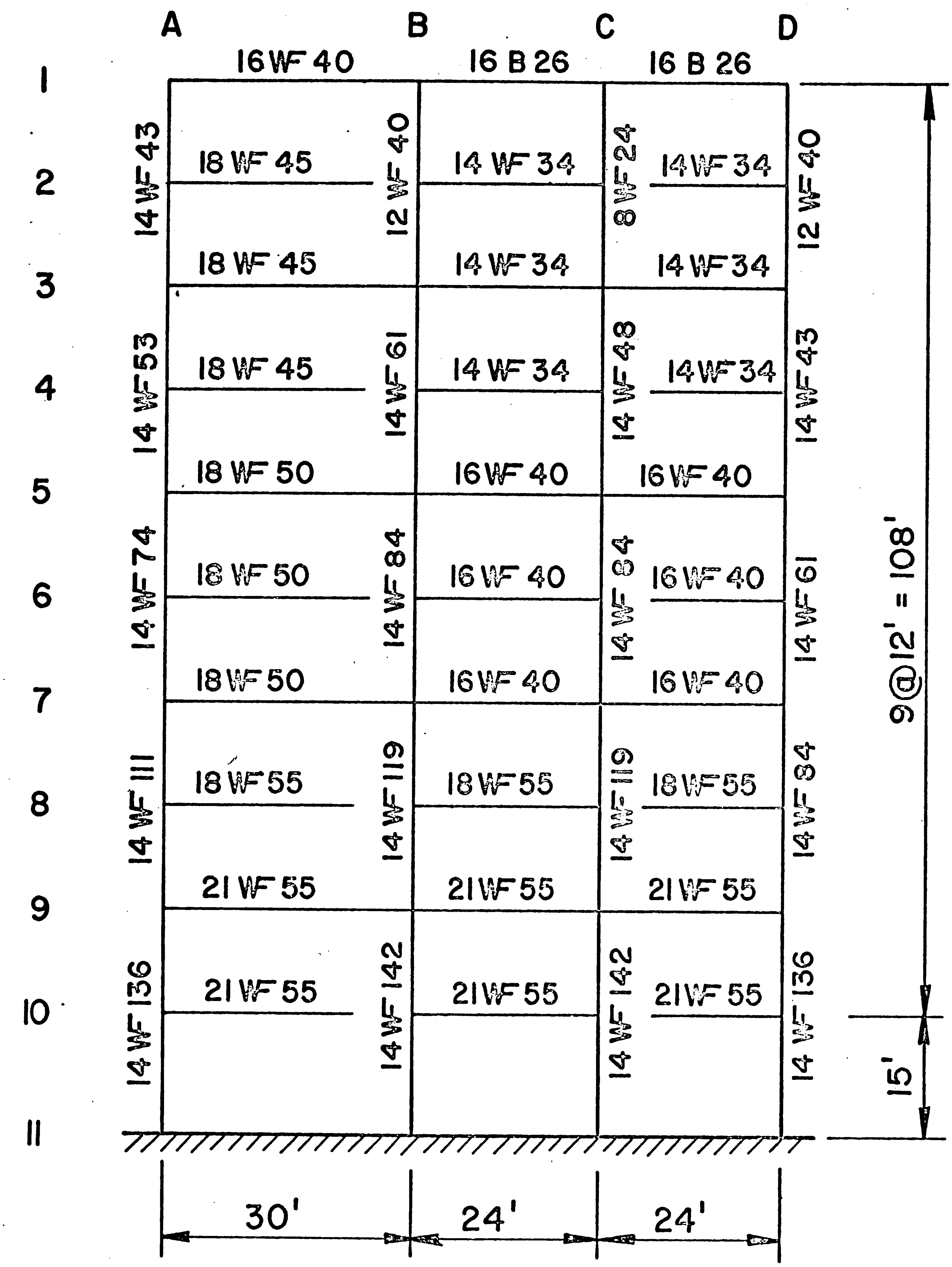


Fig. 2.2 Frame B: Member Sizes Required by Moment Balancing Method (Ref. 6)

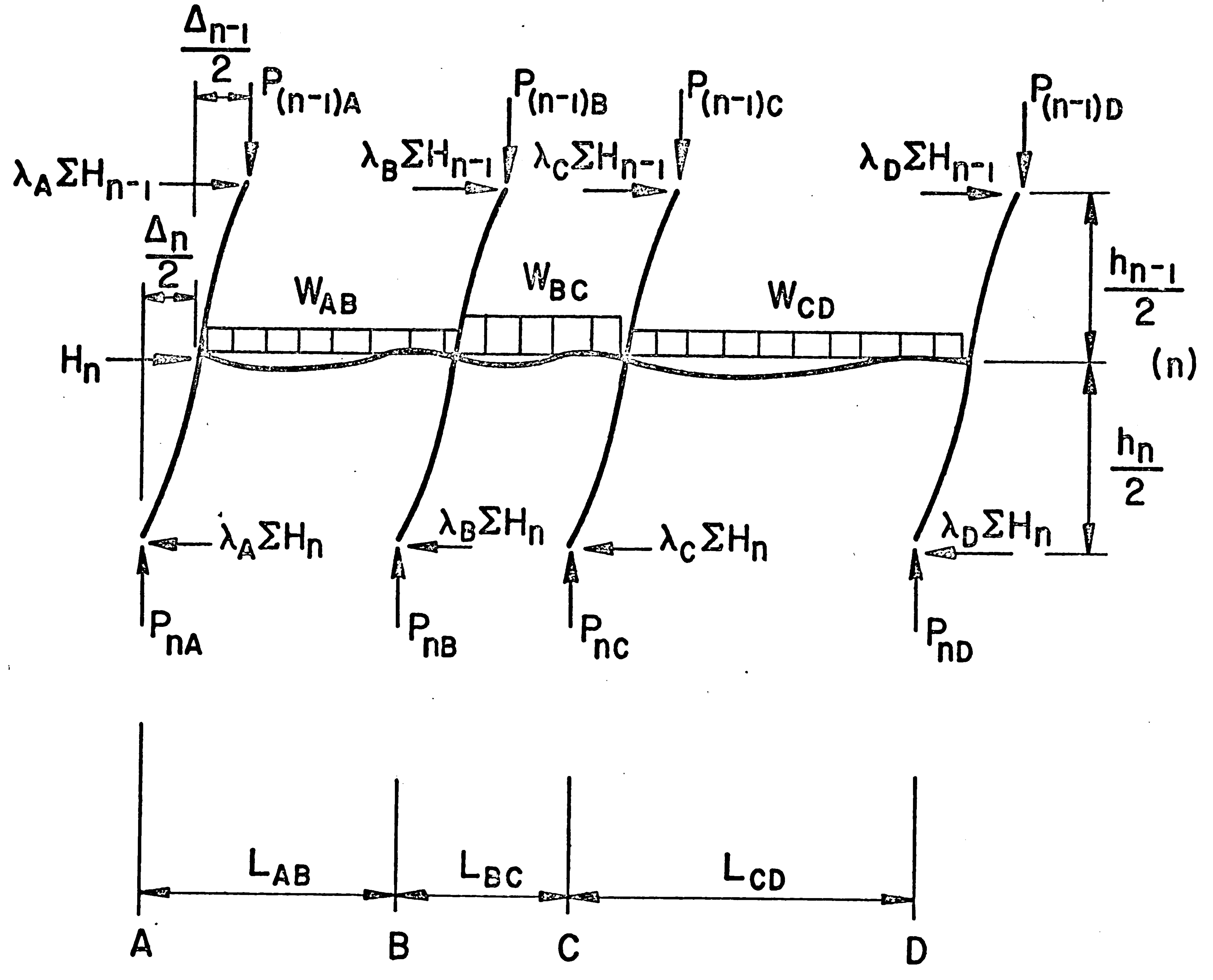


Fig. 2.3 One-Story Assemblage

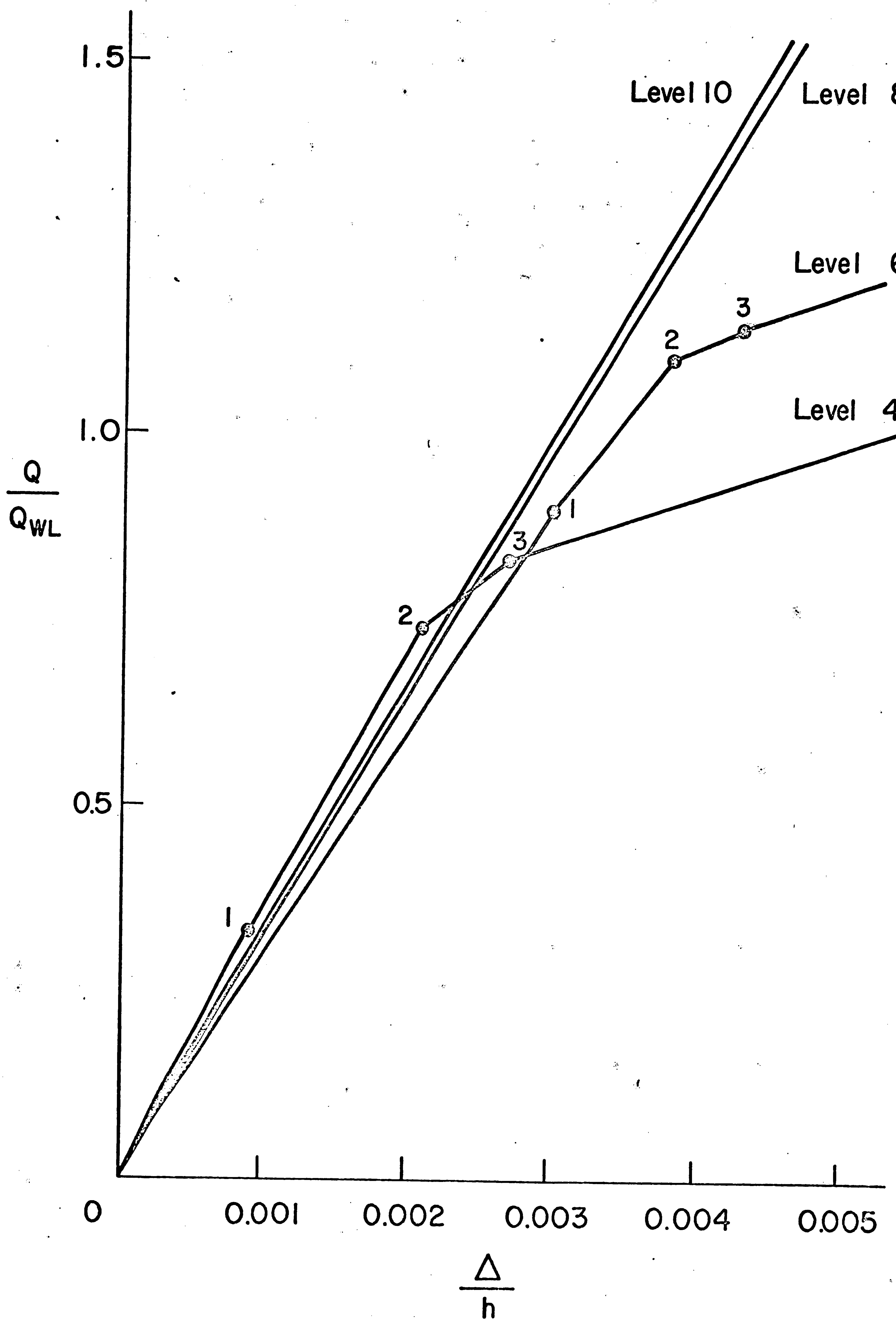


Fig. 2.4 Horizontal Force Versus Sway Deflection Under Working Combined Load

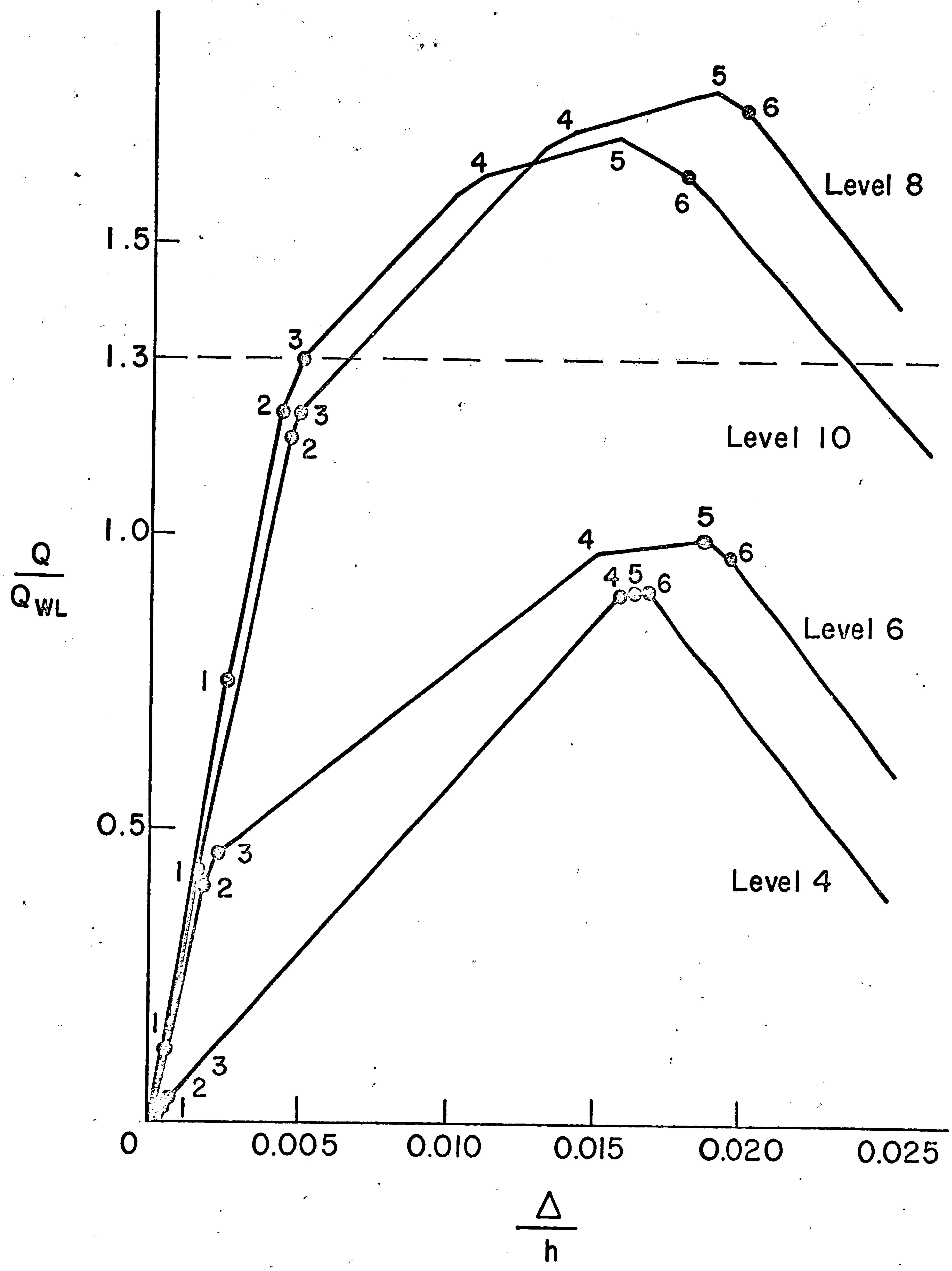


Fig. 2.5 Horizontal Force Versus Sway Deflection
Under Working Combined Load

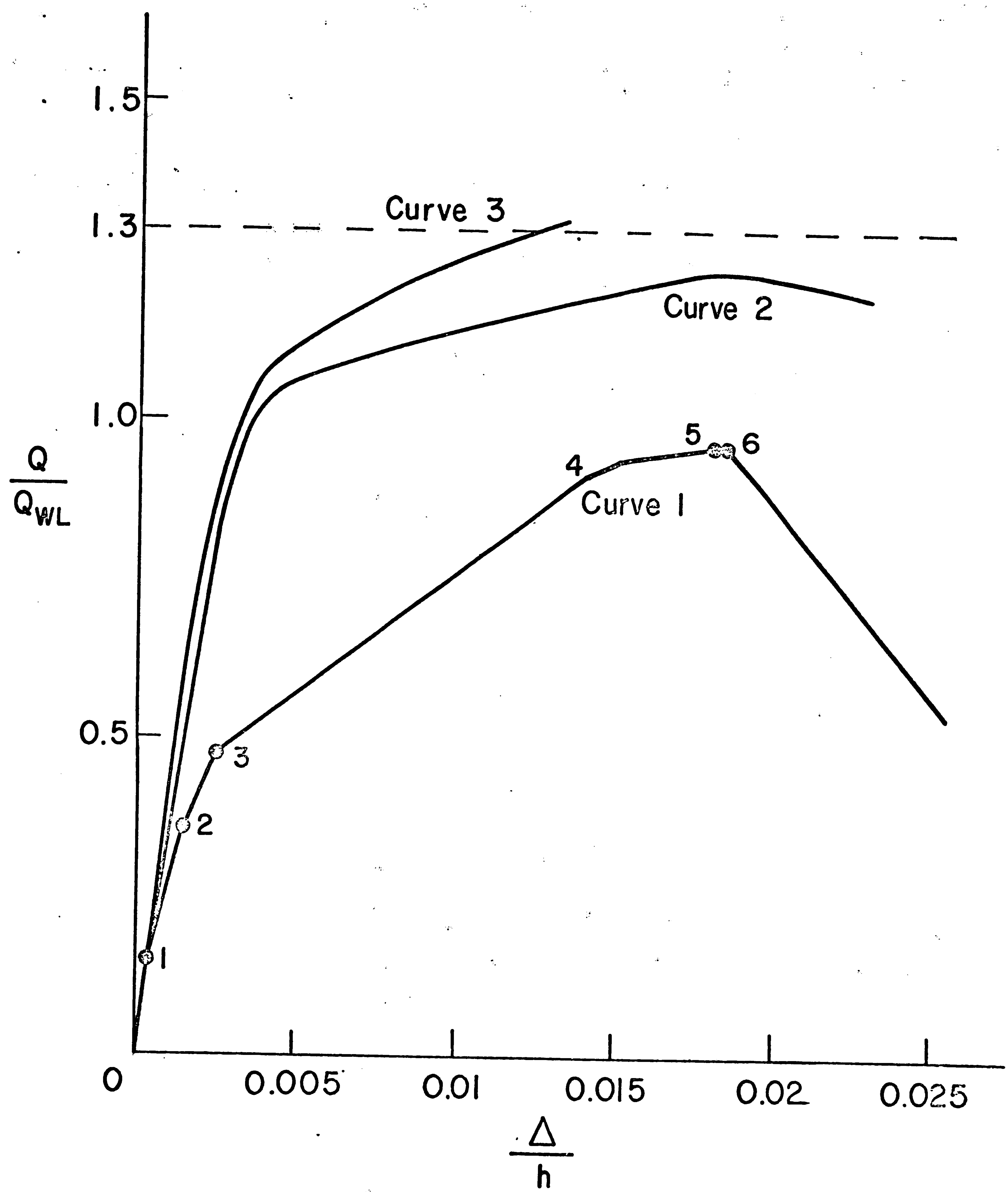


Fig. 2.6 Horizontal Force Versus Sway Deflection
(Level 6)

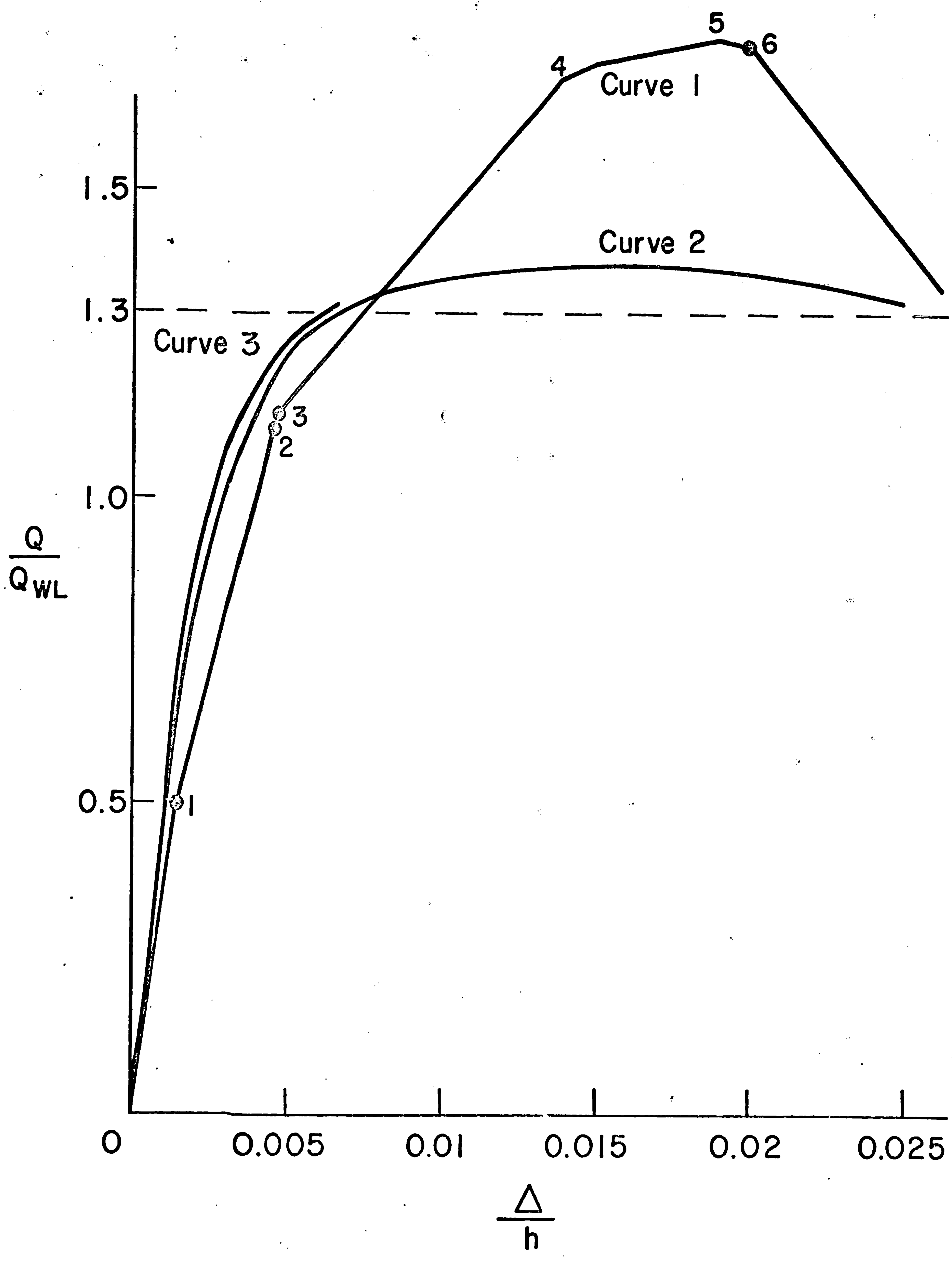


Fig. 2.7 Horizontal Force Versus Sway Deflection
(Level 8)

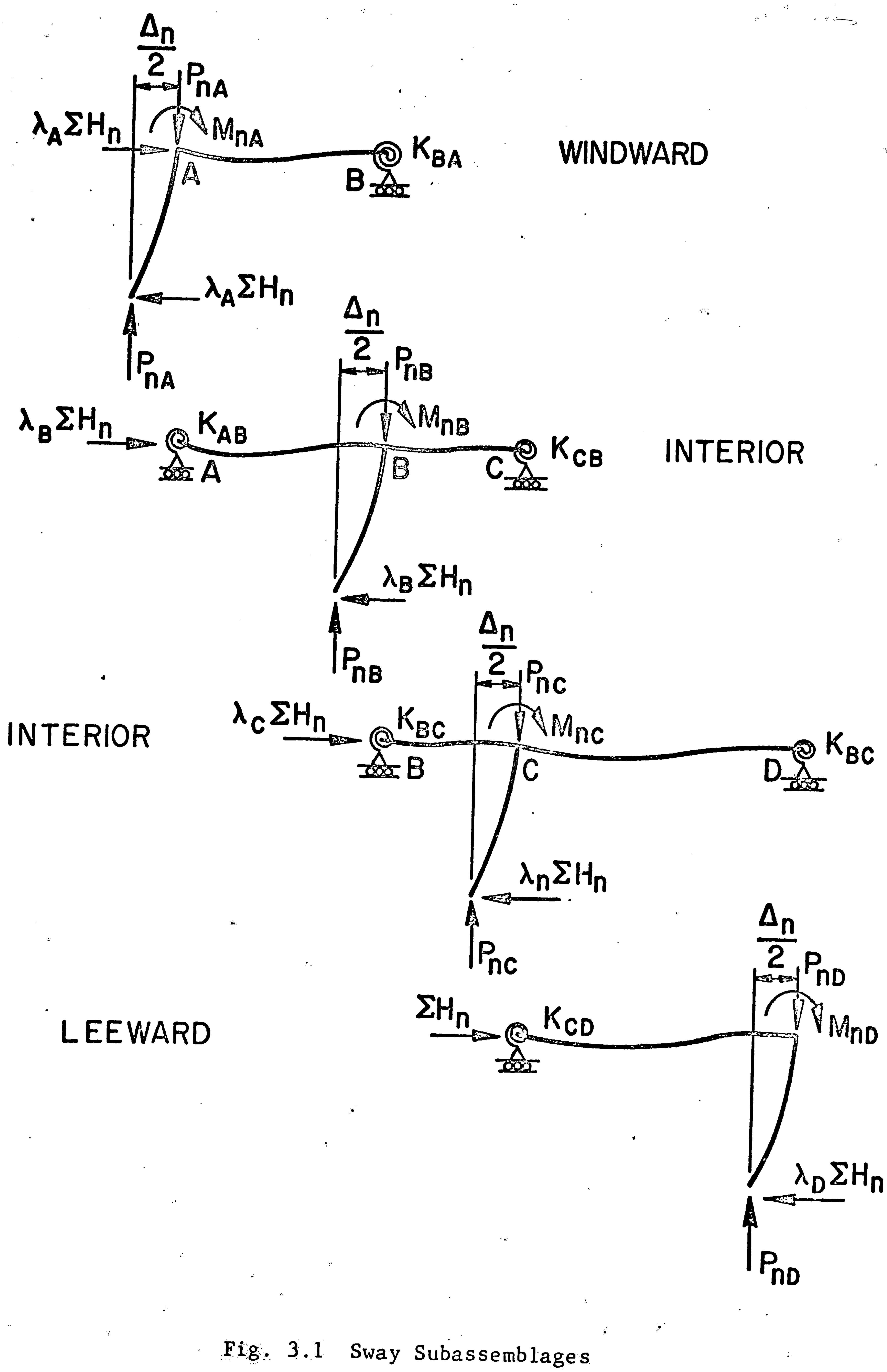
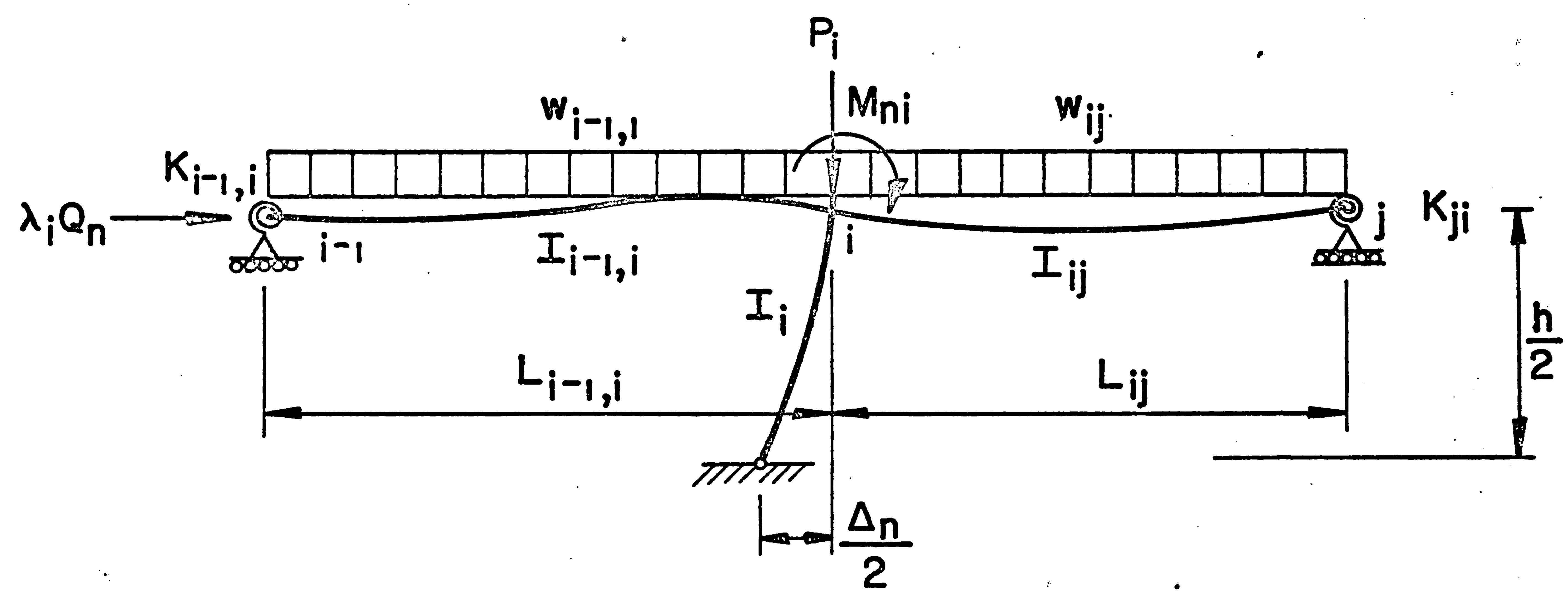
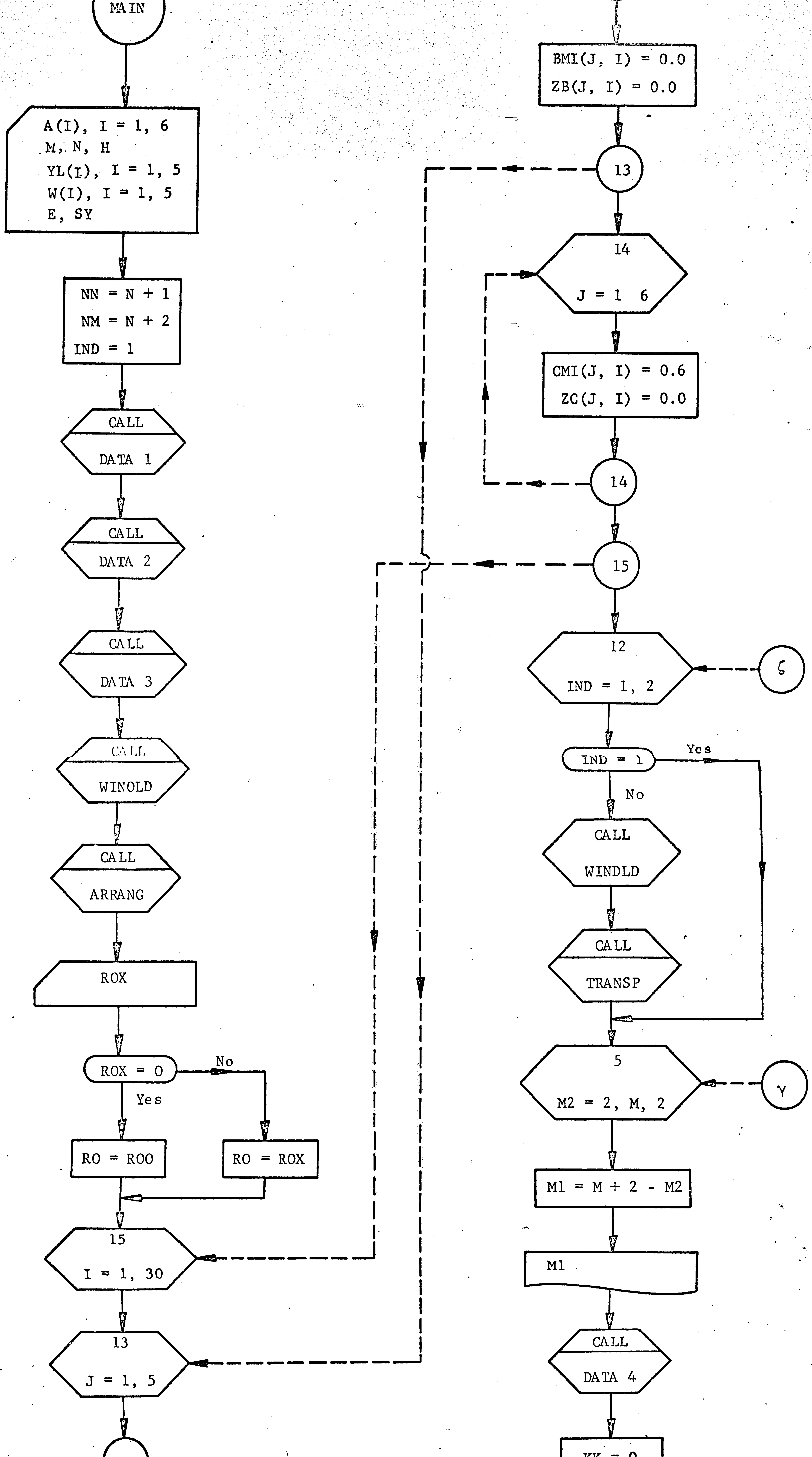


Fig. 3.1 Sway Subassemblages

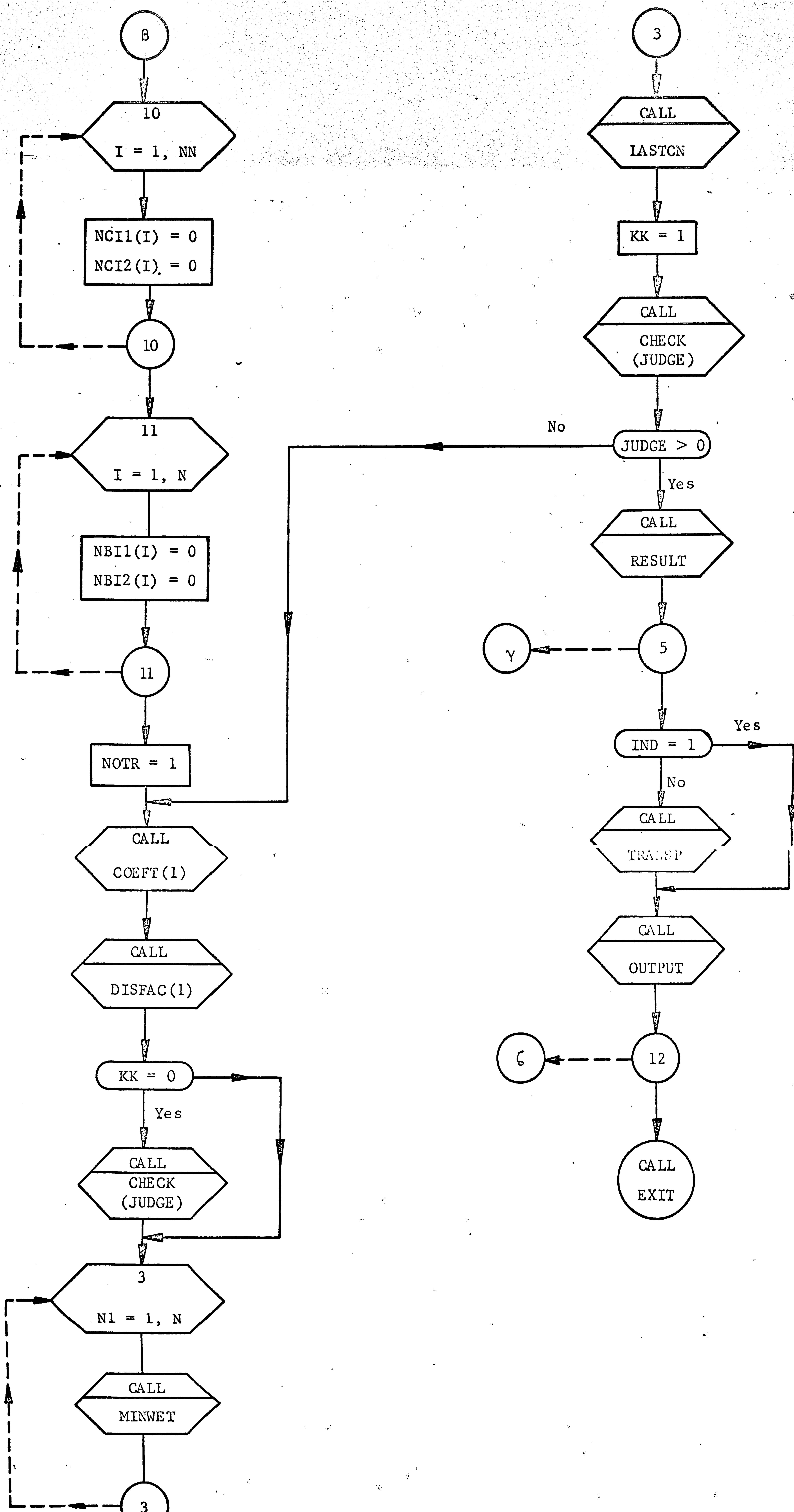


$$M_{ni} = \frac{1}{2} h \lambda_i Q_n + \frac{1}{2} \Delta_n P_{ni}$$

Fig. 3.2 An Interior Sway Subassemblage



MAIN
A(I), I = 1, 6
M, N, H
YL(I), I = 1, 5
W(I), I = 1, 5
E, SY
NN = N + 1
NM = N + 2
IND = 1
CALL
DATA 1
CALL
DATA 2
CALL
DATA 3
CALL
WINOLD
CALL
ARRANG
ROX
ROX = 0
No
Yes
RO = ROO
RO = ROX
15
I = 1, 30
13
J = 1, 5
BMI(J, I) = 0.0
ZB(J, I) = 0.0
13
14
J = 1 6
CMI(J, I) = 0.6
ZC(J, I) = 0.0
14
15
12
IND = 1, 2
IND = 1
Yes
No
CALL
WINDLD
CALL
TRANSP
5
M2 = 2, M, 2
M1 = M + 2 - M2
M1
CALL
DATA 4



β
10
I = 1, NN
NCI1(I) = 0
NCI2(I) = 0
10
11
I = 1, N
NBI1(I) = 0
NBI2(I) = 0
11
NOTR = 1
CALL
COEFT(1)
CALL
DISFAC(1)
KK = 0
Yes
CALL
CHECK
(JUDGE)
3
N1 = 1, N
CALL
MINWET
3
3
CALL
LASTCN
KK = 1
CALL
CHECK
(JUDGE)
JUDGE > 0
No
Yes
CALL
RESULT
5
γ
IND = 1
Yes
No
CALL
CALL
OUTPUT
12
ζ
CALL
EXIT

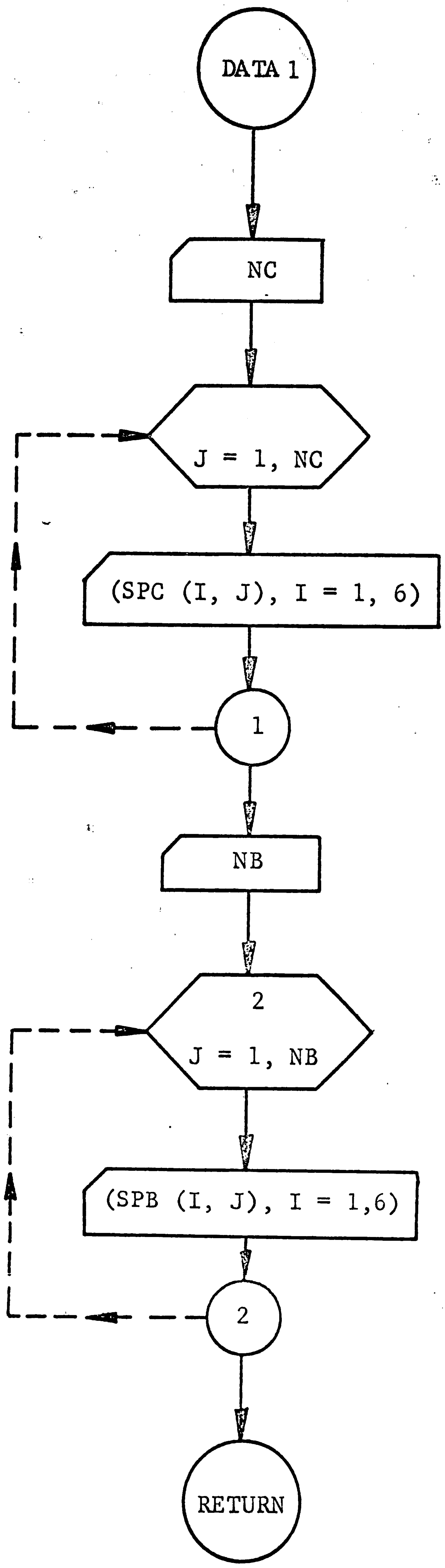
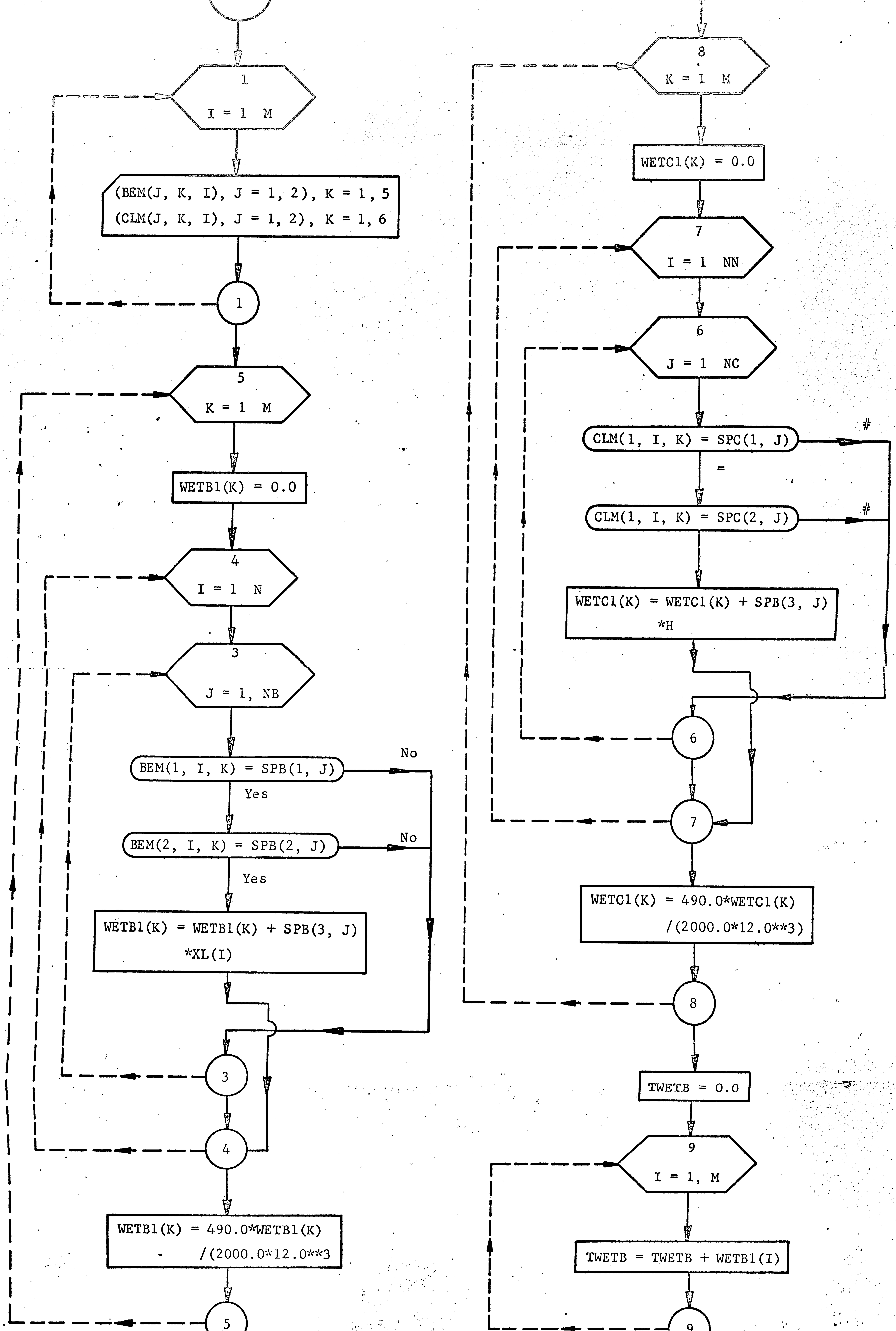


Fig. 4.3 Flow Chart of Subroutine DATA 1


1
I = 1 M
(BEM(J, K, I), J = 1, 2), K = 1, 5
(CLM(J, K, I), J = 1, 2), K = 1, 6
1
5
K = 1 M
WETB1(K) = 0.0
4
I = 1 N
3
J = 1, NB
BEM(1, I, K) = SPB(1, J)
No
Yes
BEM(2, I, K) = SPB(2, J)
No
Yes
WETB1(K) = WETB1(K) + SPB(3, J) *XL(I)
3
4
WETB1(K) = 490.0*WETB1(K) /(2000.0*12.0**3
5
8
K = 1 M
WETC1(K) = 0.0
7
I = 1 NN
6
J = 1 NC
CLM(1, I, K) = SPC(1, J)
#
=
CLM(1, I, K) = SPC(2, J)
#
WETC1(K) = WETC1(K) + SPB(3, J) *H
6
7
WETC1(K) = 490.0*WETC1(K) /(2000.0*12.0**3)
8
TWETB = 0.0
9
I = 1, M
TWETB = TWETB + WETB1(I)
9

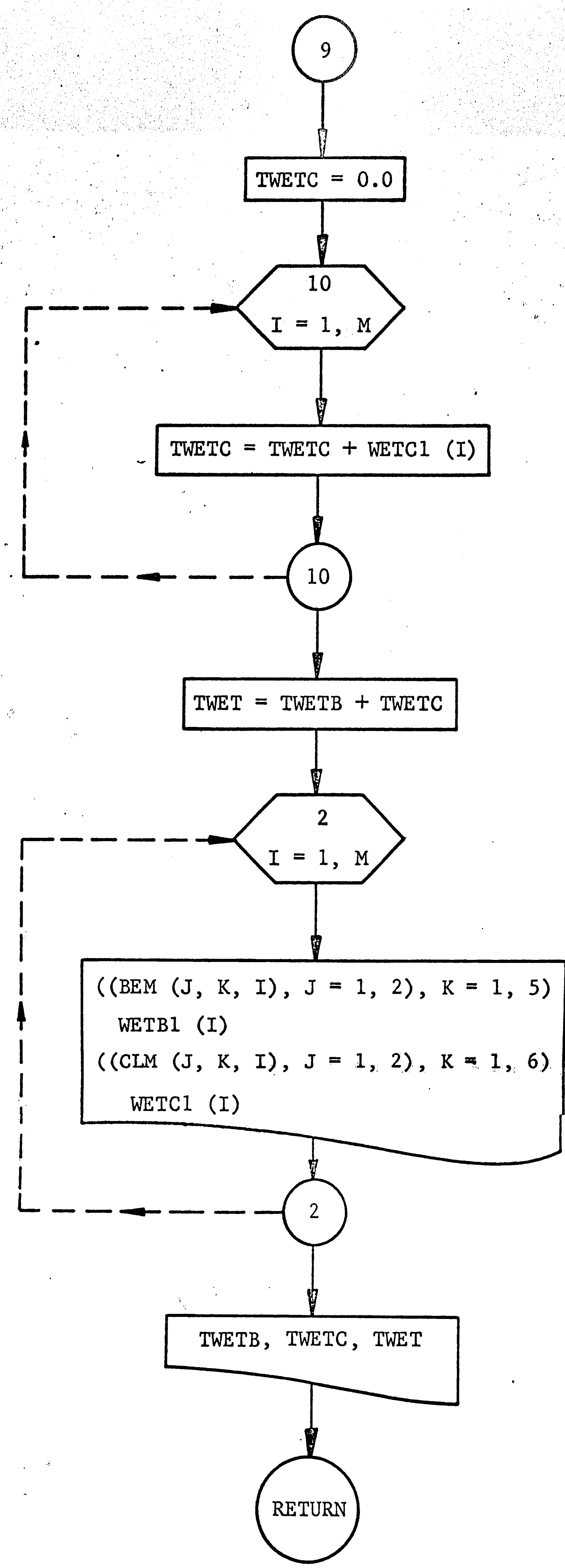


Fig. 4.5 Flow Chart of Subroutine DATA 2 (continued)

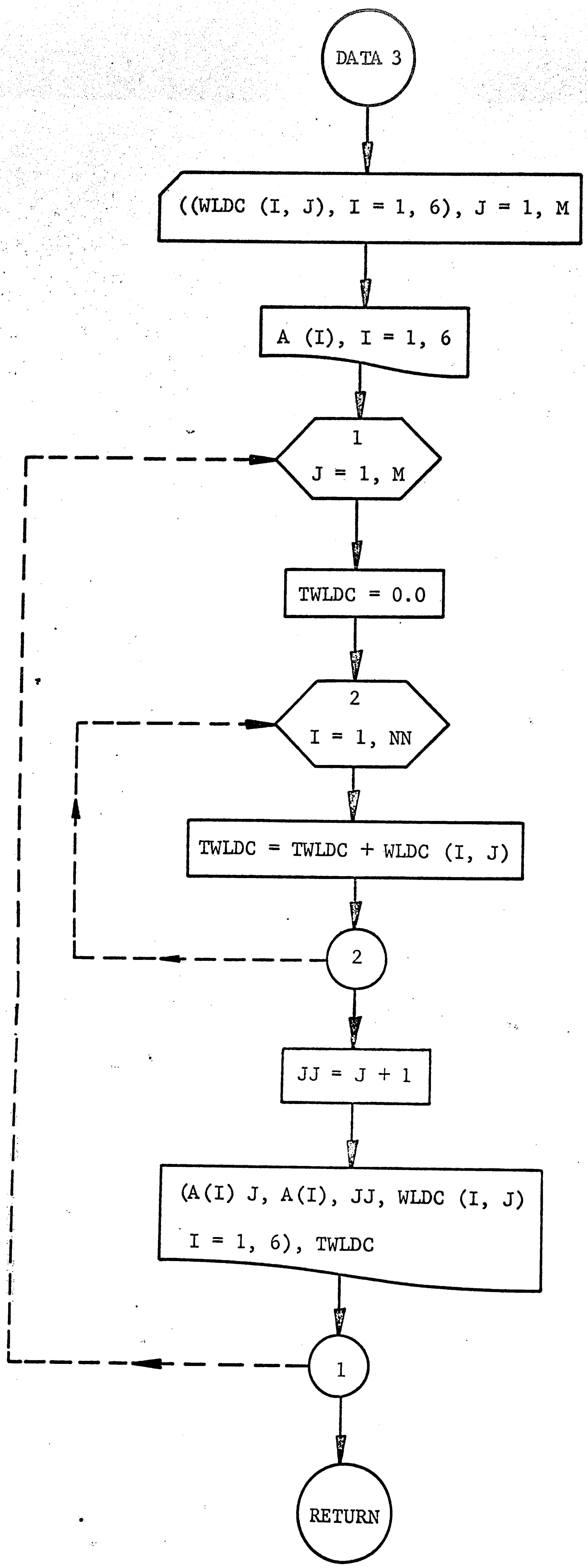
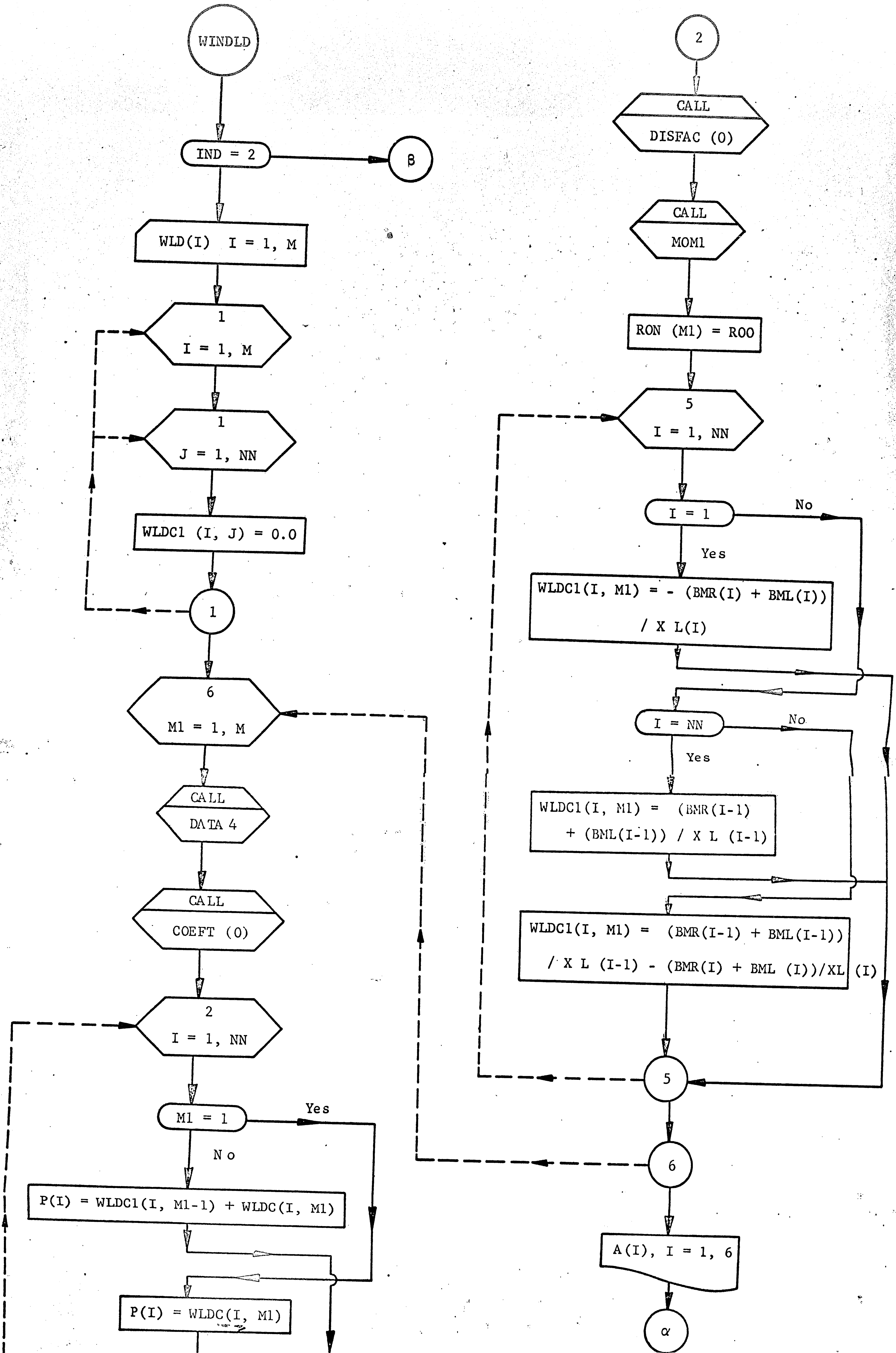
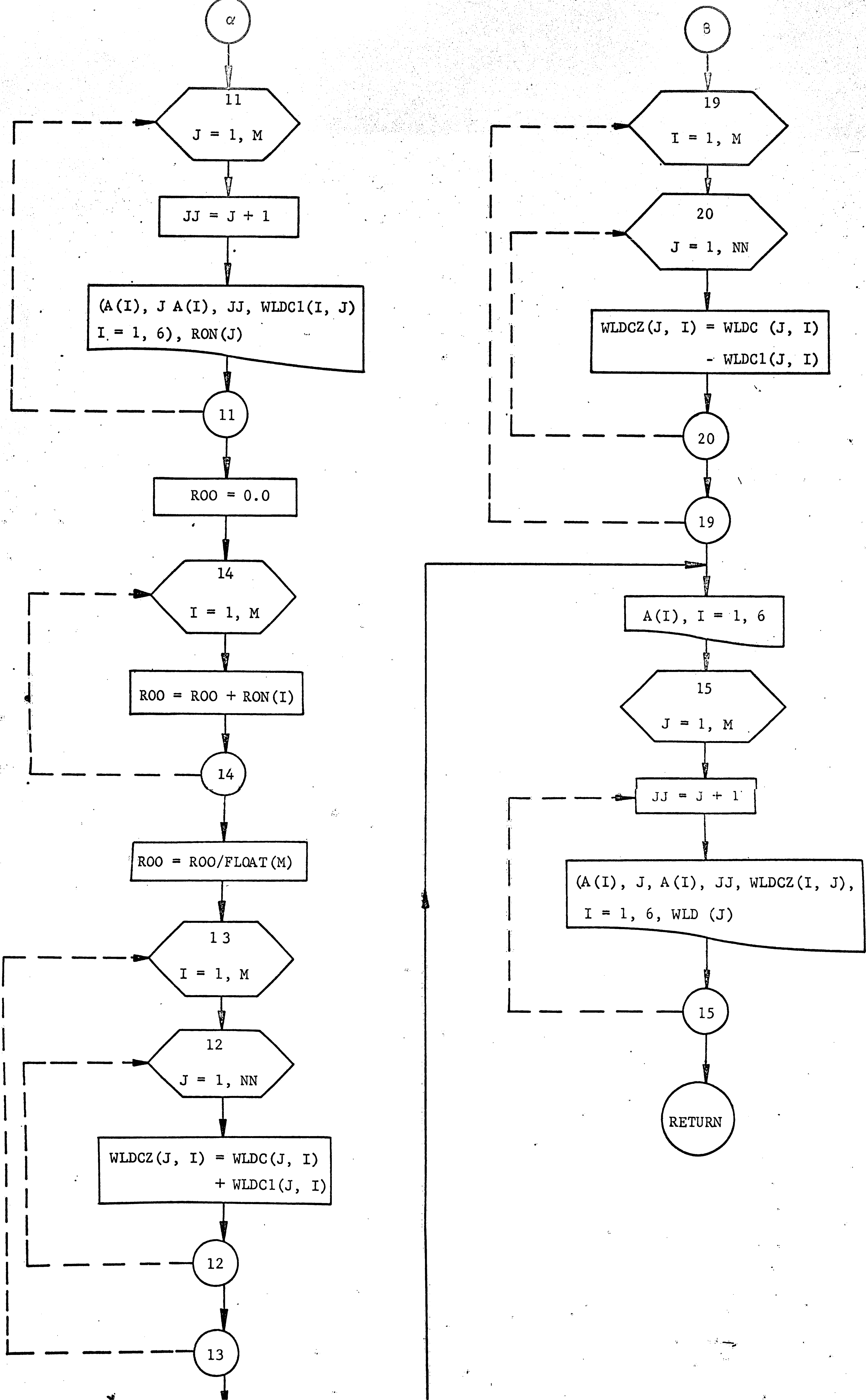
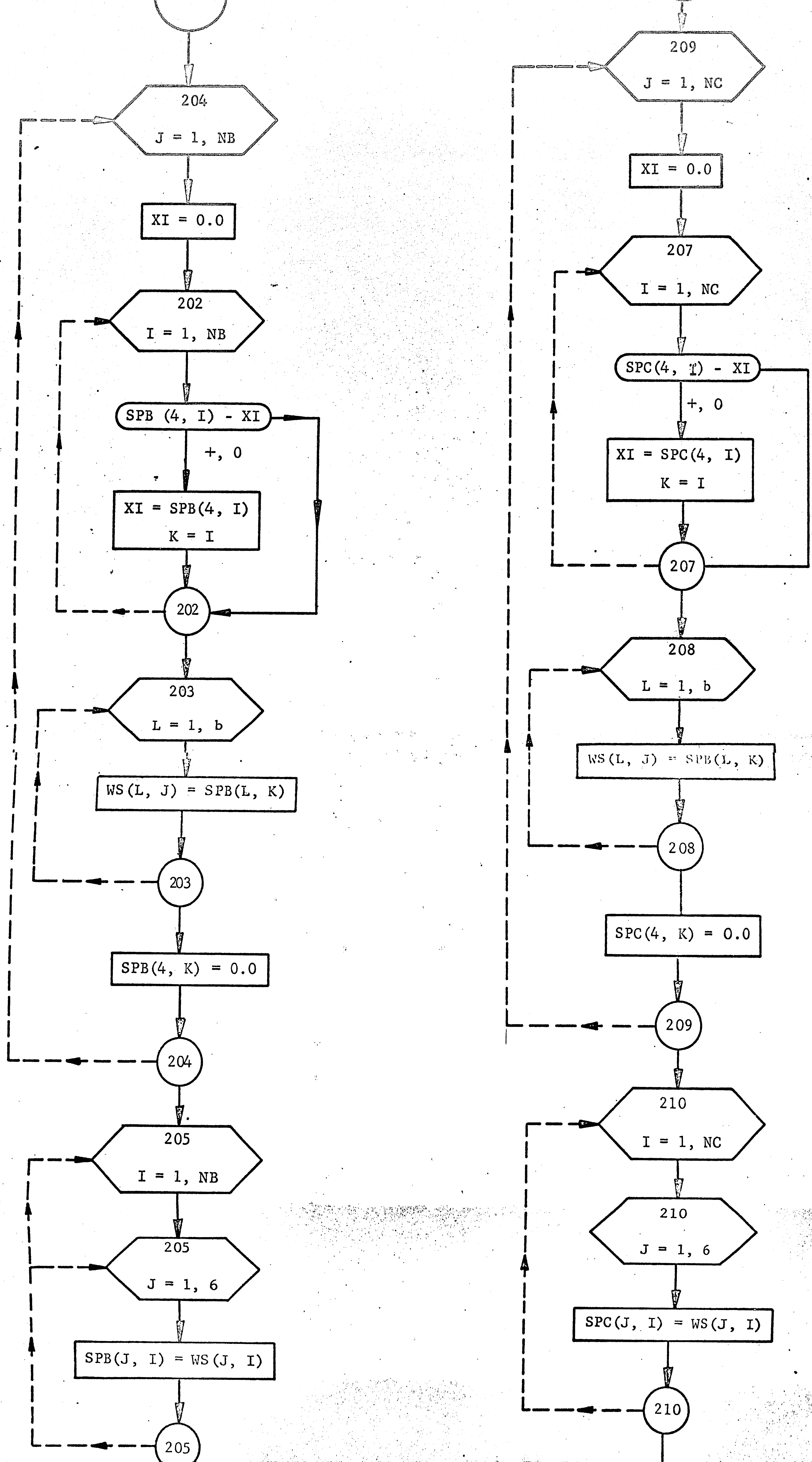


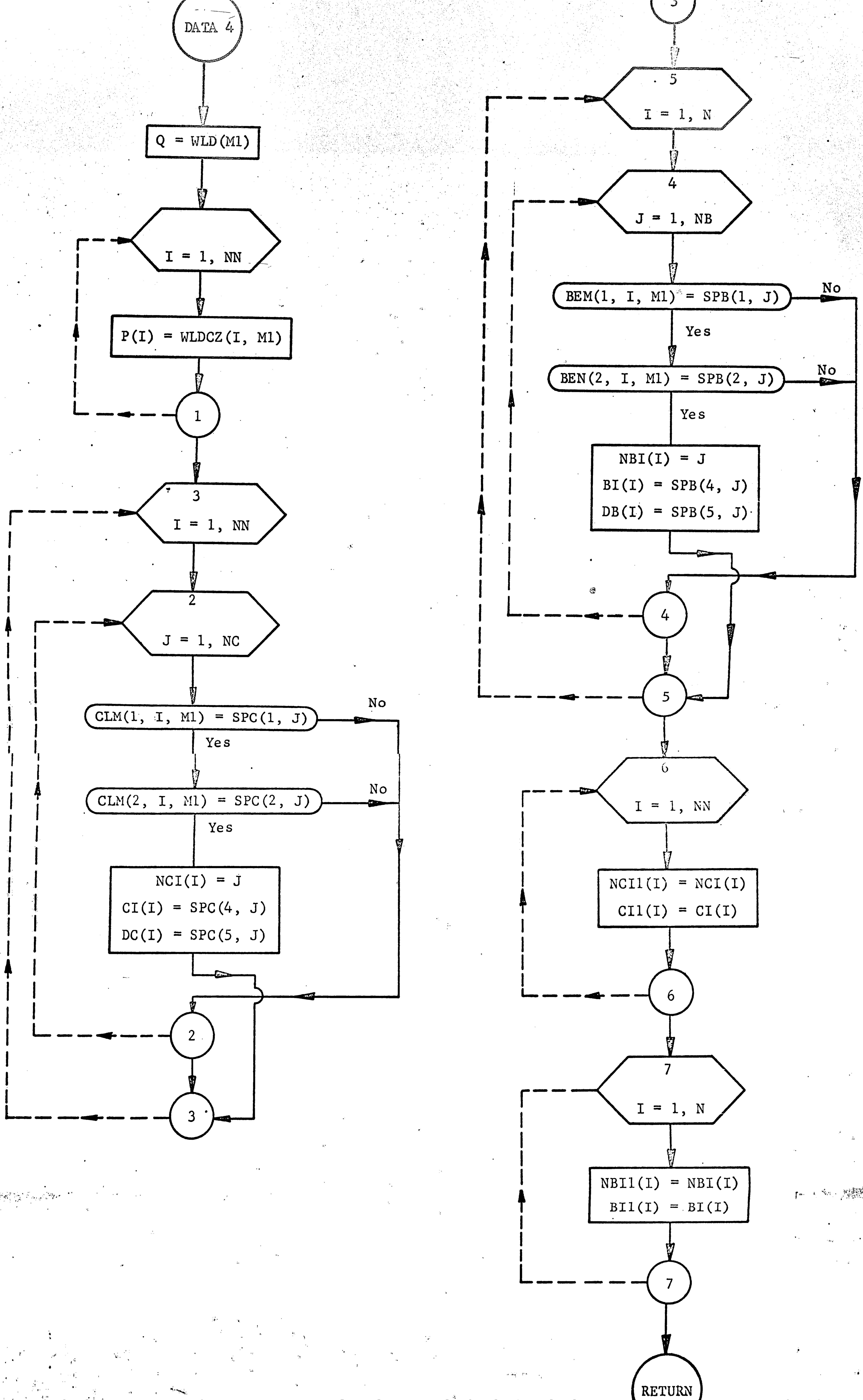
Fig. 4.6 Flow Chart of Subroutine DATA 3


WINDLD
IND = 2
β
WLD(I) I = 1, M
1
I = 1, M
1
J = 1, NN
WLDC1 (I, J) = 0.0
1
6
M1 = 1, M
CALL
DATA 4
CALL
COEFT (0)
2
I = 1, NN
M1 = 1
Yes
No
P(I) = WLDC1(I, M1-1) + WLDC(I, M1)
P(I) = WLDC(I, M1)
2
CALL
DISFAC (0)
CALL
MOM1
RON (M1) = ROO
5
I = 1, NN
I = 1
No
Yes
WLDC1(I, M1) = - (BMR(I) + BML(I))
/ X L(I)
I = NN
No
Yes
WLDC1(I, M1) = (BMR(I-1)
+ (BML(I-1)) / X L (I-1)
WLDC1(I, M1) = (BMR(I-1) + BML(I-1))
/ X L (I-1) - (BMR(I) + BML (I))/XL (I)
5
6
A(I), I = 1, 6
α


α
11
J = 1, M
JJ = J + 1
(A(I), J A(I), JJ, WLDC1(I, J)
I = 1, 6), RON(J)
11
ROO = 0.0
14
I = 1, M
ROO = ROO + RON(I)
14
ROO = ROO/FLOAT(M)
13
I = 1, M
12
J = 1, NN
WLDCZ(J, I) = WLDC(J, I)
+ WLDC1(J, I)
12
13
β
19
I = 1, M
20
J = 1, NN
WLDCZ(J, I) = WLDC (J, I)
- WLDC1(J, I)
20
19
A(I), I = 1, 6
15
J = 1, M
JJ = J + 1
(A(I), J, A(I), JJ, WLDCZ(I, J),
I = 1, 6, WLD (J)
15
RETURN

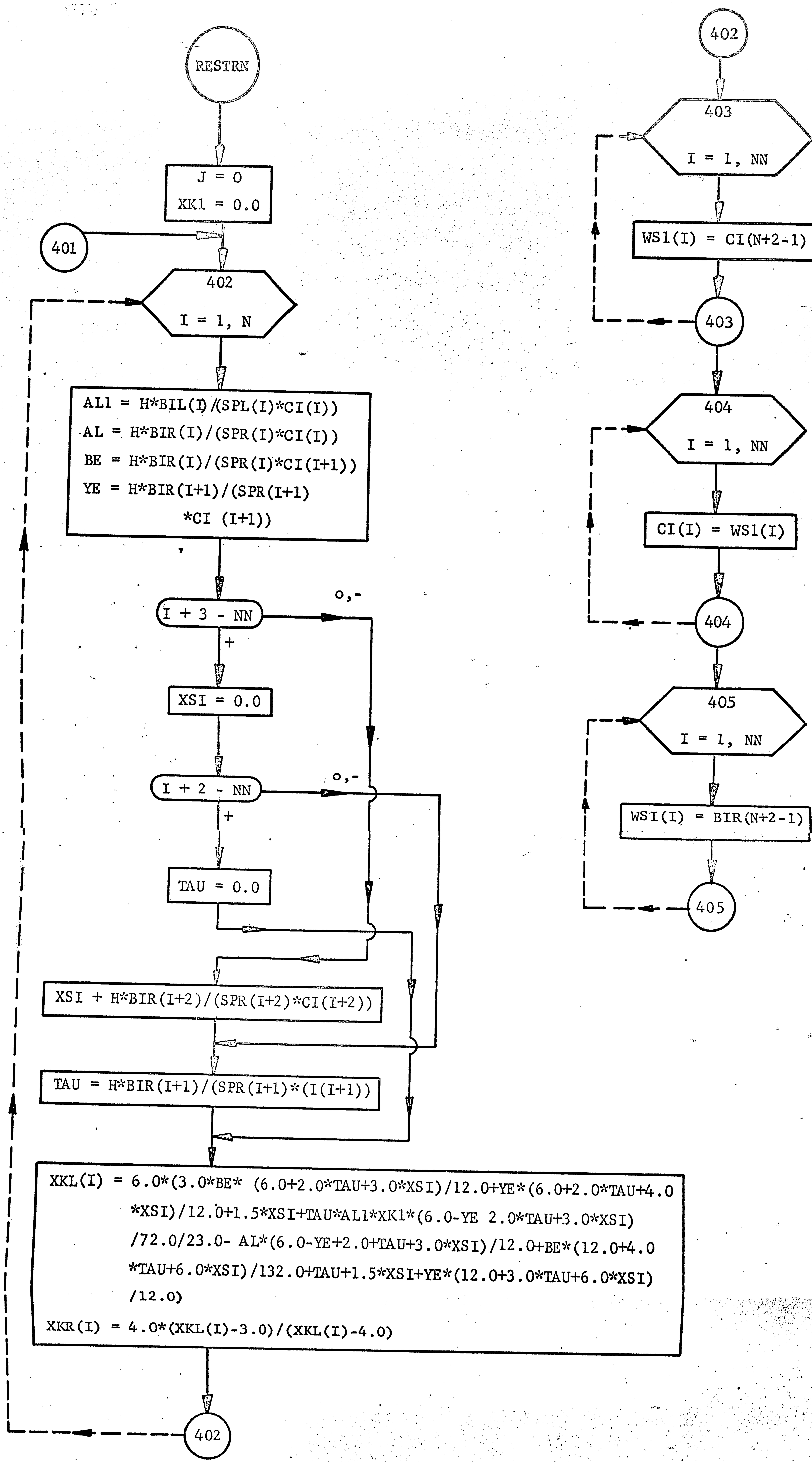


204
J = 1, NB
XI = 0.0
202
I = 1, NB
SPB (4, I) - XI
+, 0
XI = SPB(4, I)
K = I
202
203
L = 1, b
WS(L, J) = SPB(L, K)
203
SPB(4, K) = 0.0
204
205
I = 1, NB
205
J = 1, 6
SPB(J, I) = WS(J, I)
205
209
J = 1, NC
XI = 0.0
207
I = 1, NC
SPC(4, I) - XI
+, 0
XI = SPC(4, I)
K = I
207
208
L = 1, b
WS(L, J) = SPB(L, K)
208
SPC(4, K) = 0.0
209
210
I = 1, NC
210
J = 1, 6
SPC(J, I) = WS(J, I)
210

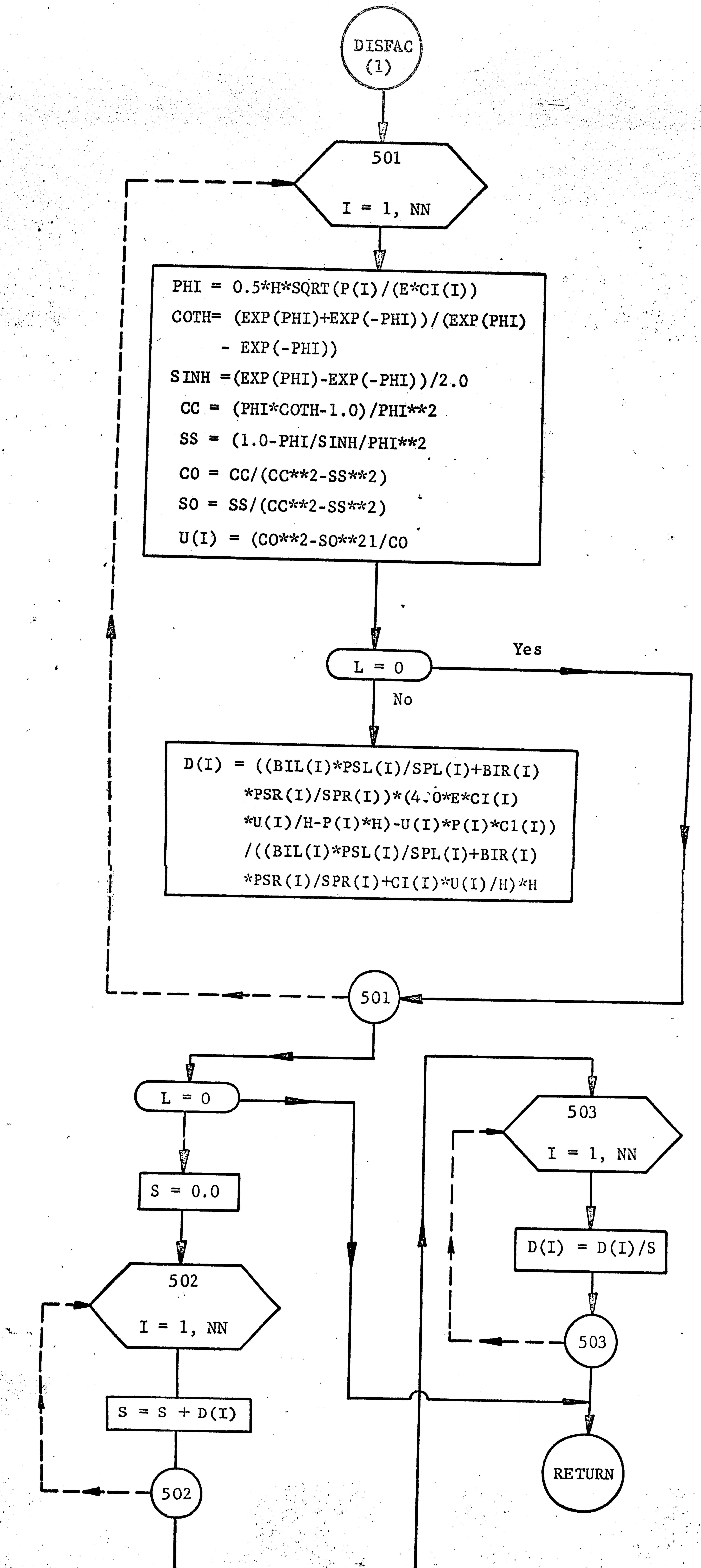


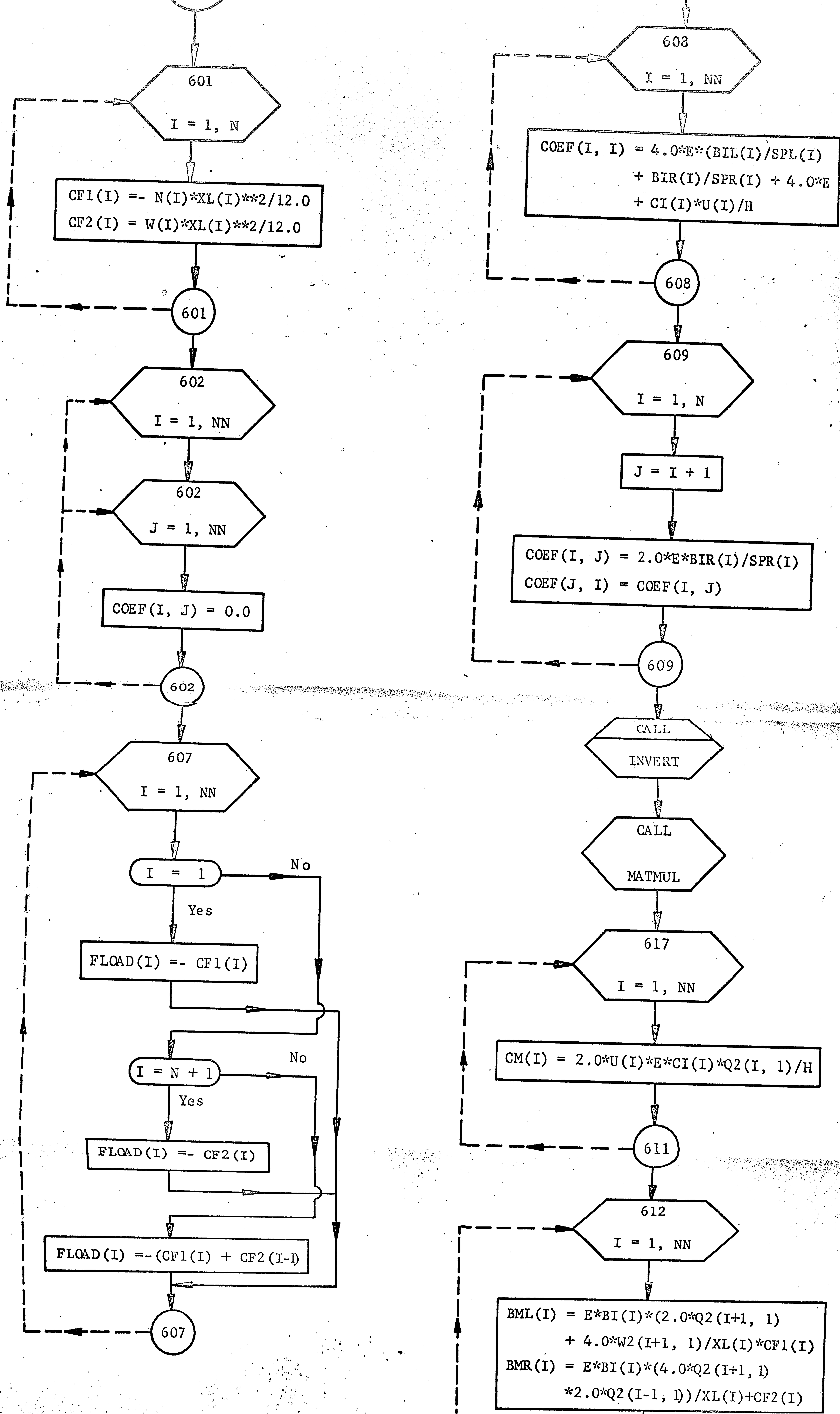
DATA 4
Q = WLD(M1)
I = 1, NN
P(I) = WLDCZ(I, M1)
1
3
I = 1, NN
2
J = 1, NC
CLM(1, I, M1) = SPC(1, J)
No
Yes
CLM(2, I, M1) = SPC(2, J)
No
Yes
NCI(I) = J
CI(I) = SPC(4, J)
DC(I) = SPC(5, J)
2
3
5
I = 1, N
4
J = 1, NB
BEM(1, I, M1) = SPB(1, J)
No
Yes
BEN(2, I, M1) = SPB(2, J)
No
Yes
NBI(I) = J
BI(I) = SPB(4, J)
DB(I) = SPB(5, J)
4
5
6
I = 1, NN
NCI1(I) = NCI(I)
CI1(I) = CI(I)
6
7
I = 1, N
NBI1(I) = NBI(I)
BI1(I) = BI(I)
7
RETURN

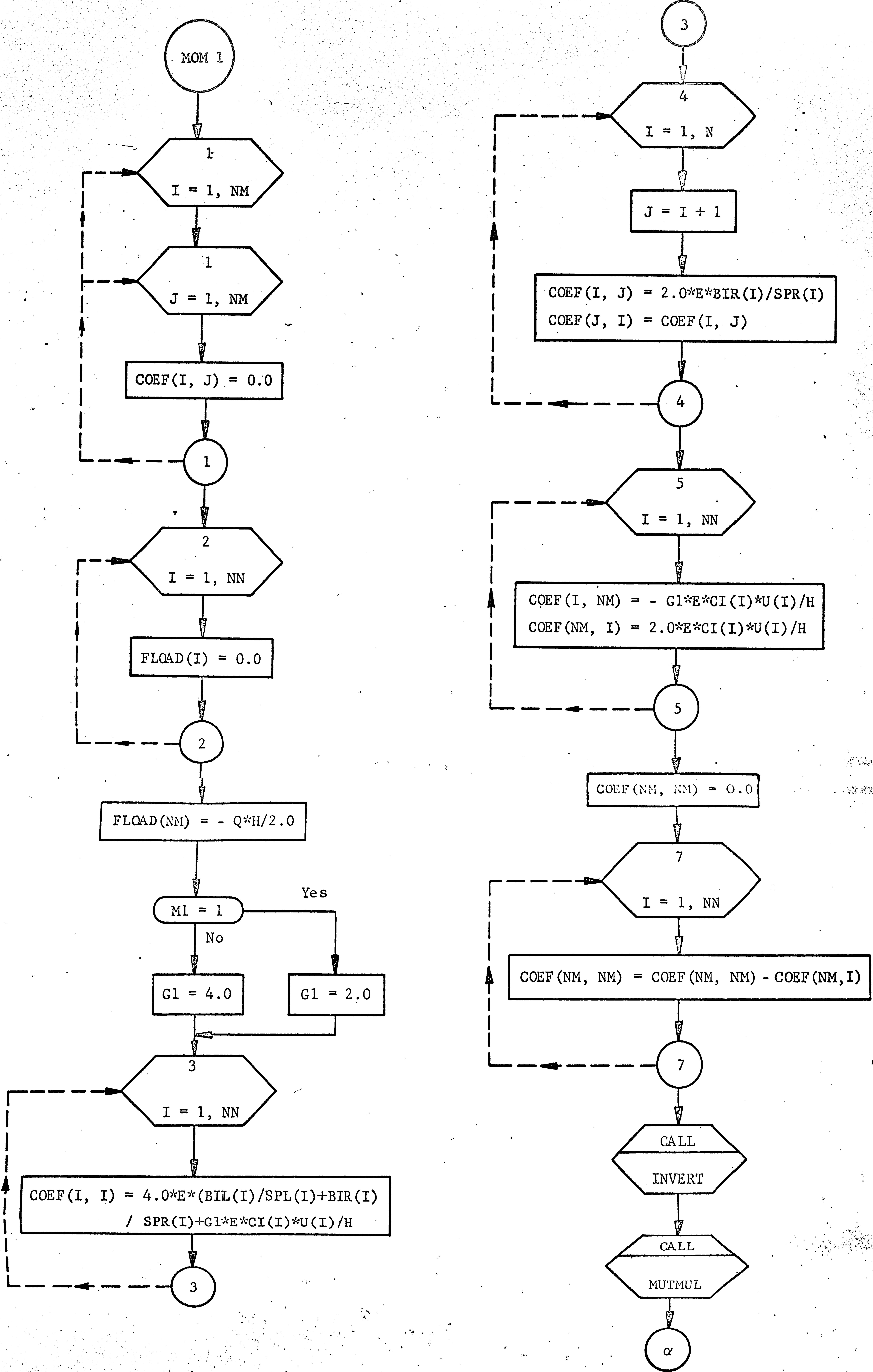
COEFT (L)
314
I = 1, NN
I = 1
Yes
No
BIL(I) = 0.0
SPL(I) = 1.0
Yes
I = N + 1
No
BIR(I) = 0.0
SPR(I) = 1.0
BIR(I) = BI(I)
SPR(I) = XL(I)
I = 1
Yes
No
BIL(I) = BI(I-1)
SPL(I) = XL(I-1)
314
L = 0
Yes
No
CALL
RESTRN
313
I = 1, NN
I = 1
Yes
No
PSL(I) = 0.0
Yes
I = N + 1
No
PSR(I) = (3.0-XKR(I))/(4.0-XKR(I))
PSR(I) = 0.0
I = 1
Yes
No


RESTRN
J = 0
XK1 = 0.0
401
402
I = 1, N
AL1 = H*BIL(I)/(SPL(I)*CI(I))
AL = H*BIR(I)/(SPR(I)*CI(I))
BE = H*BIR(I)/(SPR(I)*CI(I+1))
YE = H*BIR(I+1)/(SPR(I+1)
*CI (I+1))
I + 3 - NN
0,-
+
XSI = 0.0
I + 2 - NN
0,-
+
TAU = 0.0
XSI + H*BIR(I+2)/(SPR(I+2)*CI(I+2))
TAU = H*BIR(I+1)/(SPR(I+1)*(I(I+1))
XKL(I) = 6.0*(3.0*BE* (6.0+2.0*TAU+3.0*XSI)/12.0+YE*(6.0+2.0*TAU+4.0
*XSI)/12.0+1.5*XSI+TAU*AL1*XK1*(6.0-YE 2.0*TAU+3.0*XSI)
/72.0/23.0- AL*(6.0-YE+2.0+TAU+3.0*XSI)/12.0+BE*(12.0+4.0
*TAU+6.0*XSI)/132.0+TAU+1.5*XSI+YE*(12.0+3.0*TAU+6.0*XSI)
/12.0)
XKR(I) = 4.0*(XKL(I)-3.0)/(XKL(I)-4.0)
402
402
403
I = 1, NN
WS1(I) = CI(N+2-1)
403
404
I = 1, NN
CI(I) = WS1(I)
404
405
I = 1, NN
WSI(I) = BIR(N+2-1)
405


406
I = 1, NN
BIR(I) = WS1(I)
406
407
I = 1, NN
WS1(I) = BIL(+2-1)
407
408
I = 1, NN
BIL(I) = WS1(I)
408
409
I = 1, NN
WS1(I) = SPL(N+2-I)
409
410
I = 1, NN
SPL(I) = WS1(I)
410
411
I = 1, NN
WS1(I) = SPR(N+2-1)
411
412
I = 1, NN
SPR(I) = WSI(I)
412
J = 0
No
Yes
415
I = 1, N
XKL1(I) = XKL(I)
XKR1(I) = XKR(I)
415
J = 0
XK1 = 0.0
401
417
I = 1, N
XKL(I) = (XKR(N+1-I)+XKL1(I))/2.0
XKR(I) = (XKL(N+1-I)+XKR1(I))/2.0
417


DISFAC (1)
501
I = 1, NN
PHI = 0.5*H*SQRT(P(I)/(E*CI(I))
COTH= (EXP(PHI)+EXP(-PHI))/(EXP(PHI) - EXP(-PHI))
SINH =(EXP(PHI)-EXP(-PHI))/2.0
CC = (PHI*COTH-1.0)/PHI**2
SS = (1.0-PHI/SINH/PHI**2
CO = CC/(CC**2-SS**2)
SO = SS/(CC**2-SS**2)
U(I) = (CO**2-SO**21/CO
L = 0
Yes
No
D(I) = ((BIL(I)*PSL(I)/SPL(I)+BIR(I) *PSR(I)/SPR(I))*(4.0*E*CI(I) *U(I)/H-P(I)*H)-U(I)*P(I)*CI(I)) /((BIL(I)*PSL(I)/SPL(I)+BIR(I) *PSR(I)/SPR(I)+CI(I)*U(I)/H)*H
501
L = 0
S = 0.0
502
I = 1, NN
S = S + D(I)
502
503
I = 1, NN
D(I) = D(I)/S
503
RETURN


601
I = 1, N
CF1(I) =- N(I)*XL(I)**2/12.0
CF2(I) = W(I)*XL(I)**2/12.0
601
602
I = 1, NN
602
J = 1, NN
COEF(I, J) = 0.0
602
607
I = 1, NN
I = 1
No
Yes
FLOAD(I) =- CF1(I)
I = N + 1
No
Yes
FLOAD(I) =- CF2(I)
FLOAD(I) =-(CF1(I) + CF2(I-1)
607
608
I = 1, NN
COEF(I, I) = 4.0*E*(BIL(I)/SPL(I)
+ BIR(I)/SPR(I) + 4.0*E
+ CI(I)*U(I)/H
608
609
I = 1, N
J = I + 1
COEF(I, J) = 2.0*E*BIR(I)/SPR(I)
COEF(J, I) = COEF(I, J)
609
CALL
INVERT
CALL
MATMUL
617
I = 1, NN
CM(I) = 2.0*U(I)*E*CI(I)*Q2(I, 1)/H
611
612
I = 1, NN
BML(I) = E*BI(I)*(2.0*Q2(I+1, 1)
+ 4.0*W2(I+1, 1)/XL(I)*CF1(I)
BMR(I) = E*BI(I)*(4.0*Q2(I+1, 1)
*2.0*Q2(I-1, 1))/XL(I)+CF2(I)



MOM 1
1
I = 1, NM
1
J = 1, NM
COEF(I, J) = 0.0
1
2
I = 1, NN
FLOAD(I) = 0.0
2
FLOAD(NM) = - Q*H/2.0
M1 = 1
Yes
No
G1 = 4.0
G1 = 2.0
3
I = 1, NN
COEF(I, I) = 4.0*E*(BIL(I)/SPL(I)+BIR(I)
/ SPR(I)+G1*E*CI(I)*U(I)/H
3
3
4
I = 1, N
J = I + 1
COEF(I, J) = 2.0*E*BIR(I)/SPR(I)
COEF(J, I) = COEF(I, J)
4
5
I = 1, NN
COEF(I, NM) = - G1*E*CI(I)*U(I)/H
COEF(NM, I) = 2.0*E*CI(I)*U(I)/H
5
COEF(NM, NM) = 0.0
7
I = 1, NN
COEF(NM, NM) = COEF(NM, NM) - COEF(NM,I)
7
CALL
INVERT
CALL
MUTMUL
α

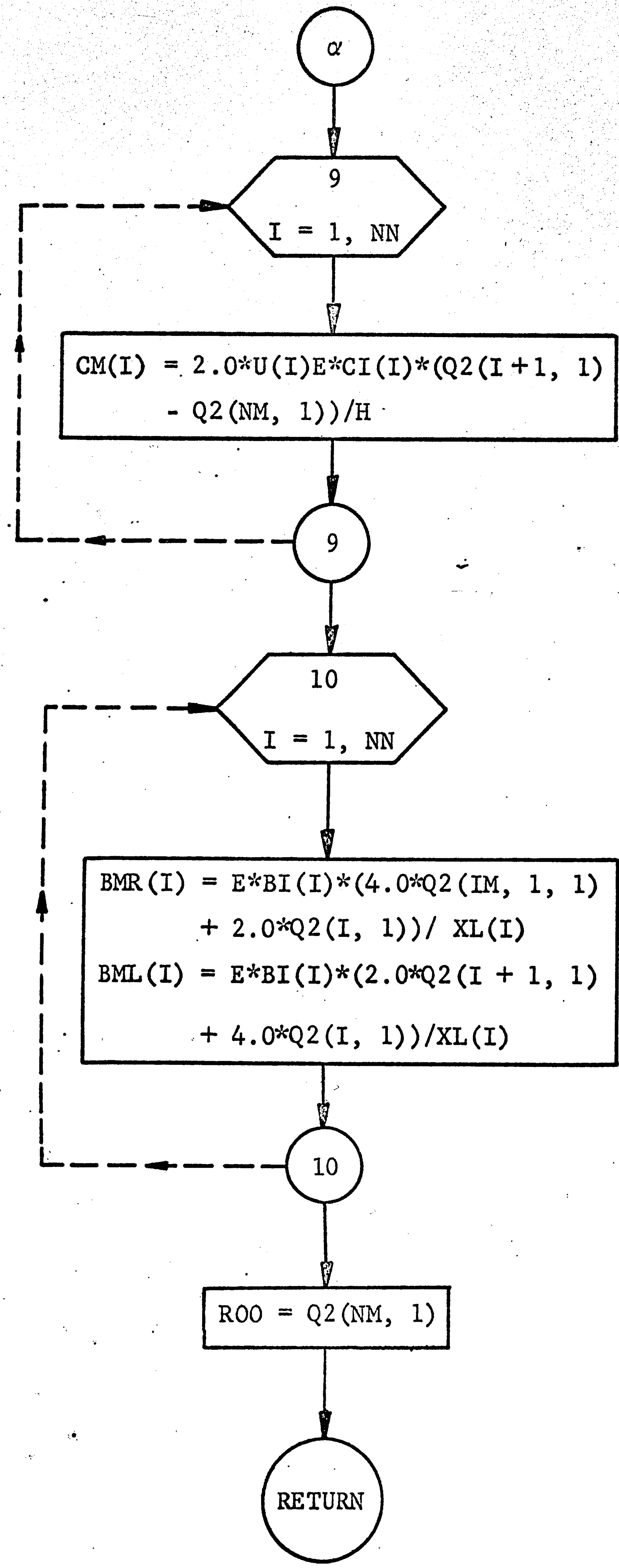
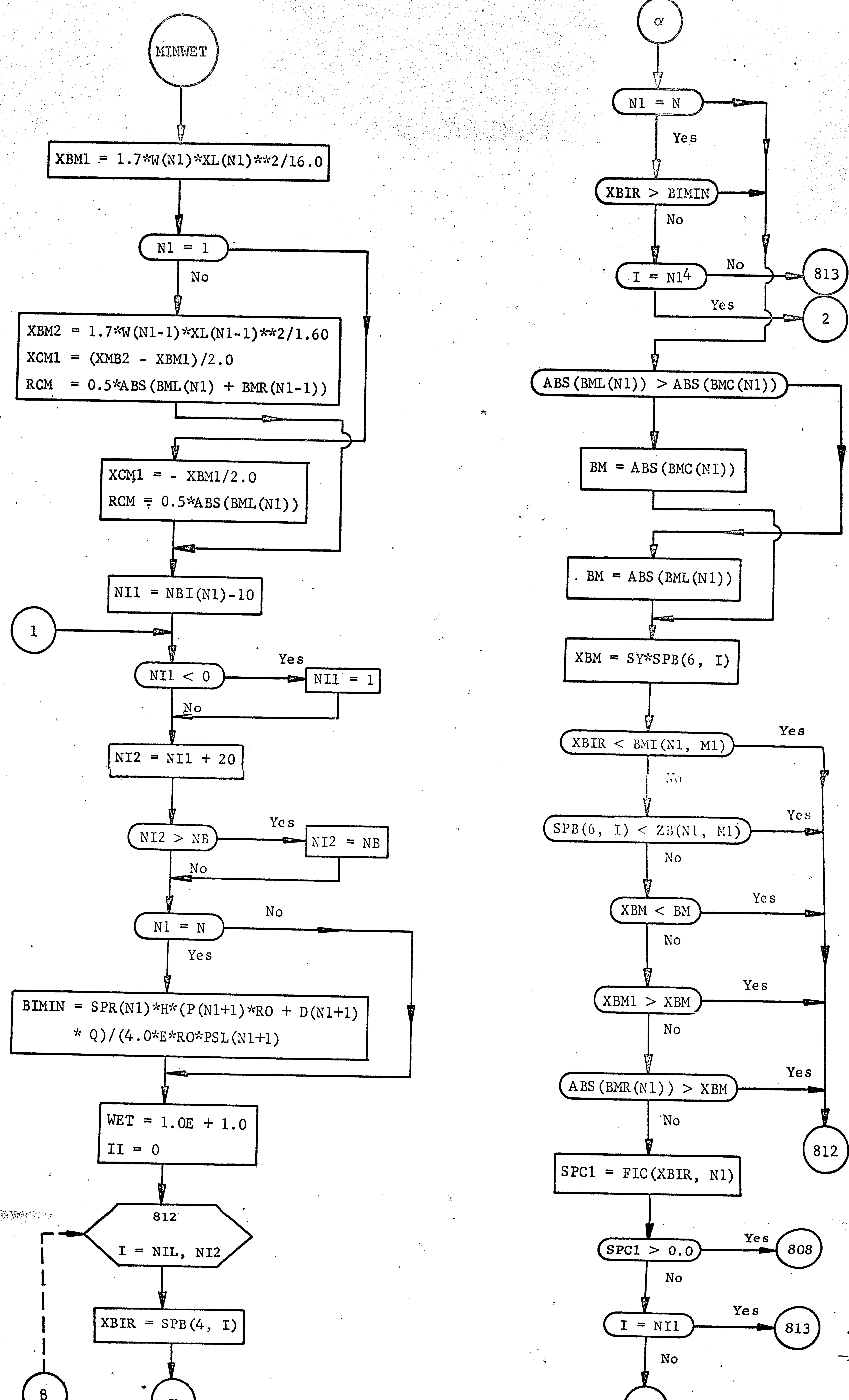
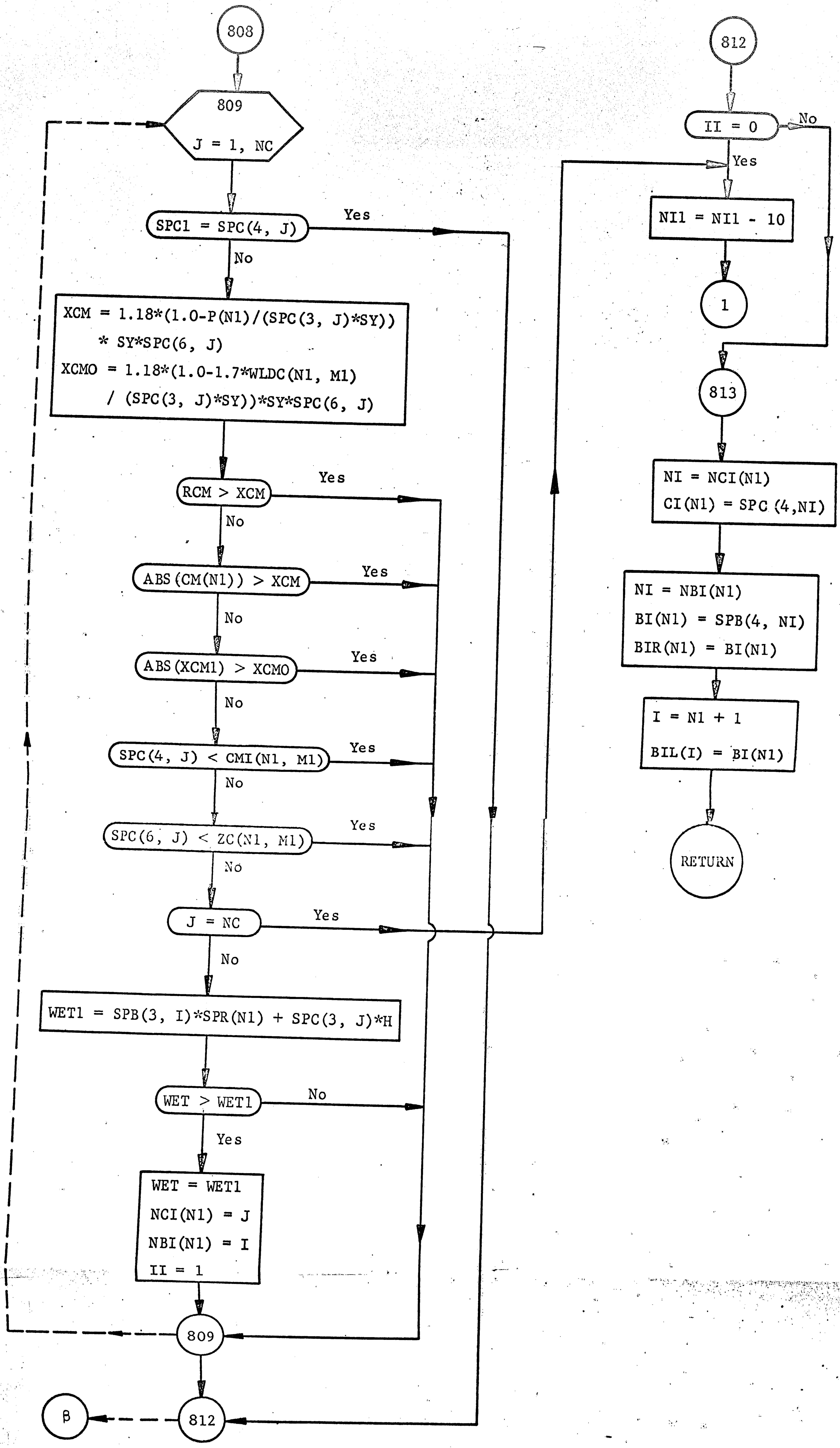
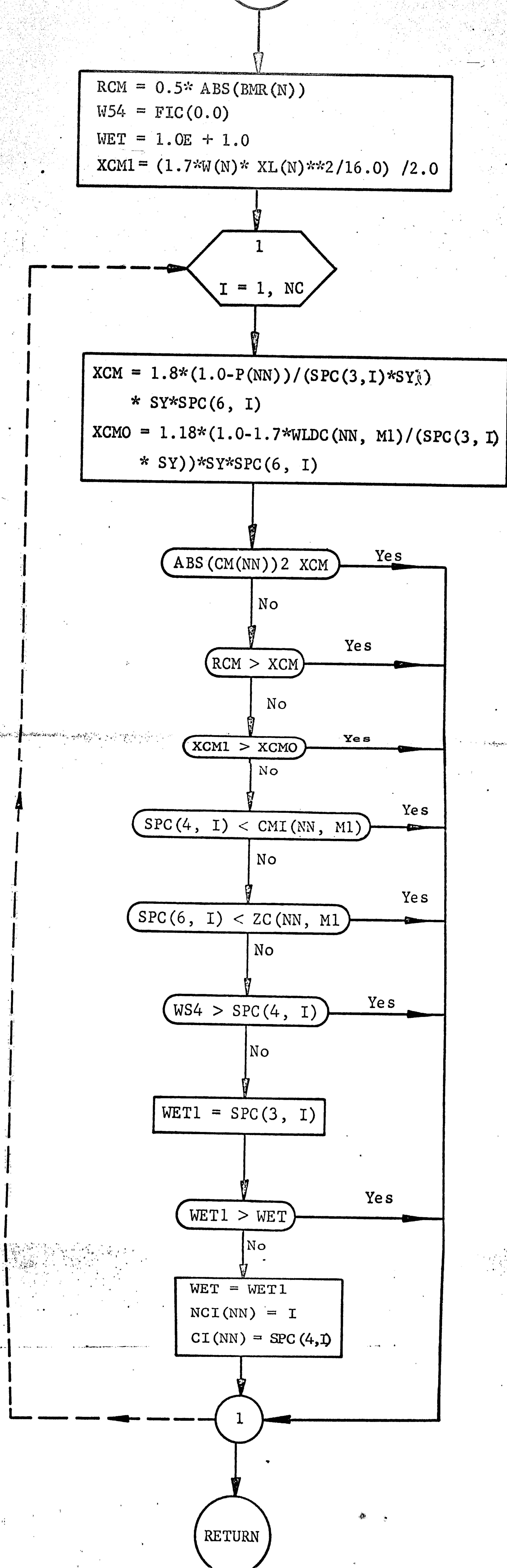
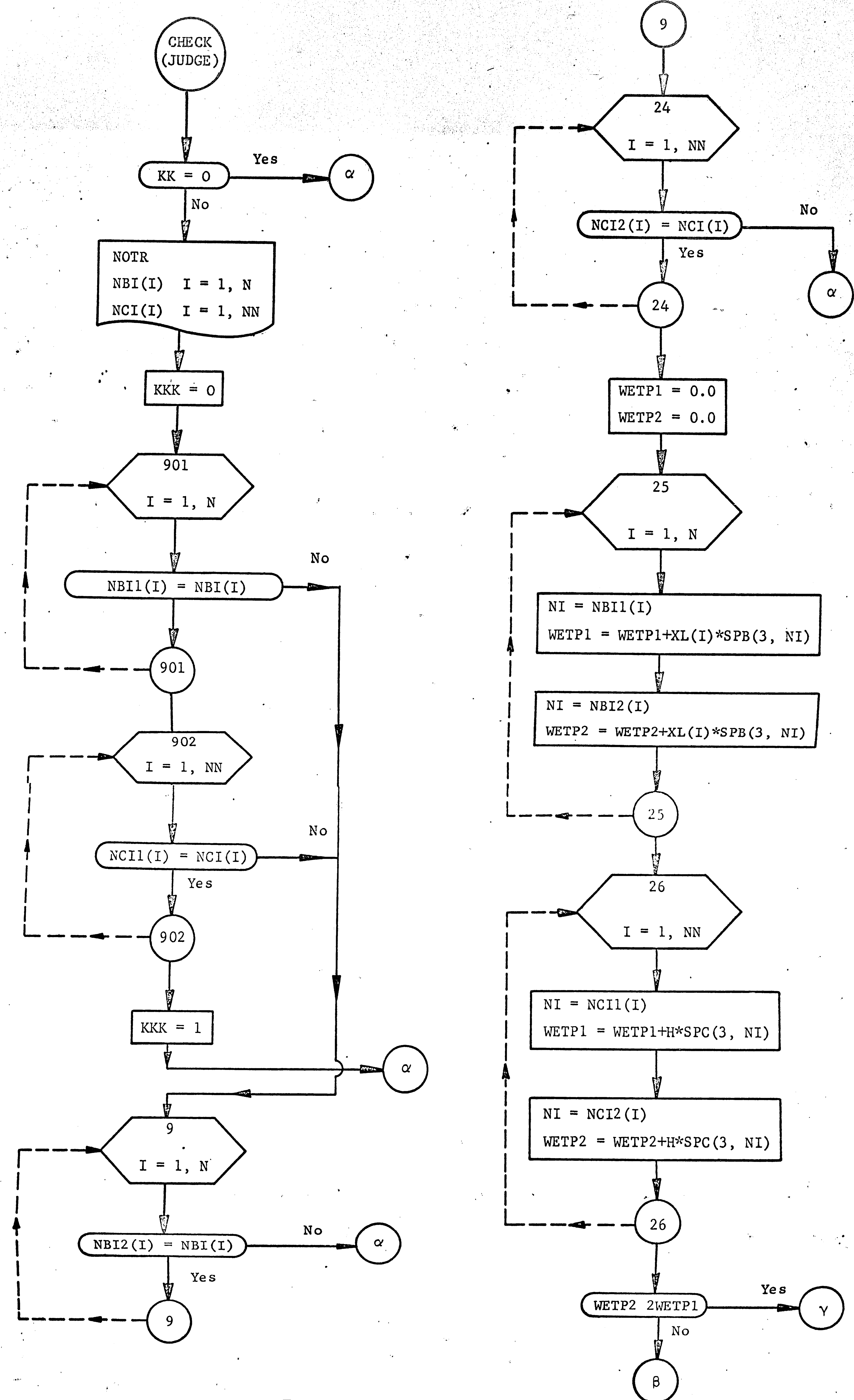


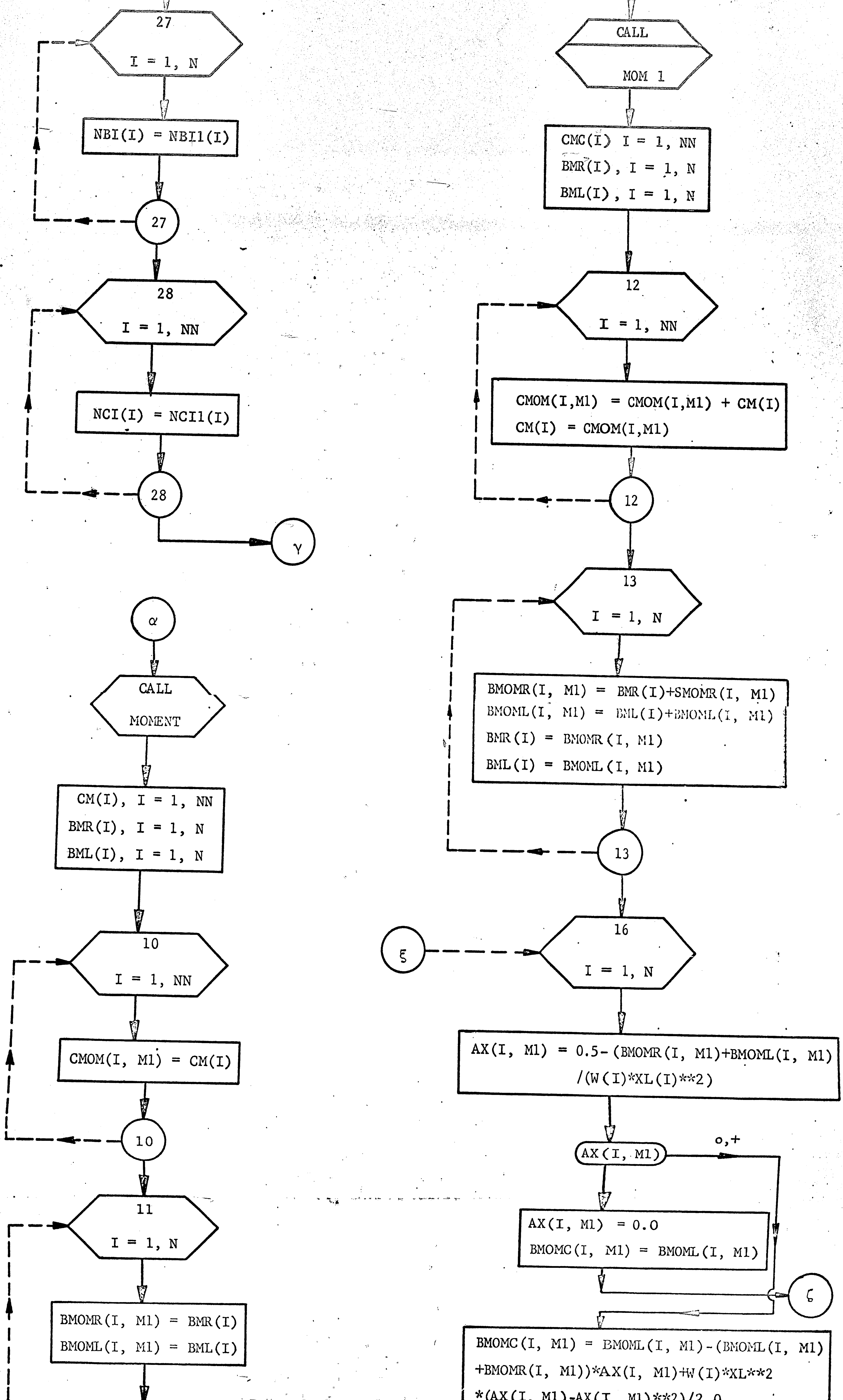
Fig. 4.17 Flow Chart of Subroutine MOM1 (continued)


MINWET
XBM1 = 1.7*W(N1)*XL(N1)**2/16.0
N1 = 1
No
XBM2 = 1.7*W(N1-1)*XL(N1-1)**2/1.60
XCM1 = (XMB2 - XBM1)/2.0
RCM = 0.5*ABS(BML(N1) + BMR(N1-1))
XCM1 = - XBM1/2.0
RCM = 0.5*ABS(BML(N1))
NI1 = NBI(N1)-10
1
NI1 < 0
Yes
NI1 = 1
No
NI2 = NI1 + 20
NI2 > NB
Yes
NI2 = NB
No
N1 = N
No
Yes
BIMIN = SPR(N1)*H*(P(N1+1)*RO + D(N1+1)
* Q)/(4.0*E*RO*PSL(N1+1)
WET = 1.0E + 1.0
II = 0
812
I = NIL, NI2
XBIR = SPB(4, I)
B
α
N1 = N
Yes
XBIR > BIMIN
No
I = N14
No
813
Yes
2
ABS(BML(N1)) > ABS(BMC(N1))
BM = ABS(BMC(N1))
BM = ABS(BML(N1))
XBM = SY*SPB(6, I)
XBIR < BMI(N1, M1)
Yes
No
SPB(6, I) < ZB(N1, M1)
Yes
No
XBM < BM
Yes
No
XBM1 > XBM
Yes
No
ABS(BMR(N1)) > XBM
Yes
No
812
SPC1 = FIC(XBIR, N1)
SPC1 > 0.0
Yes
808
No
I = NI1
Yes
813
No

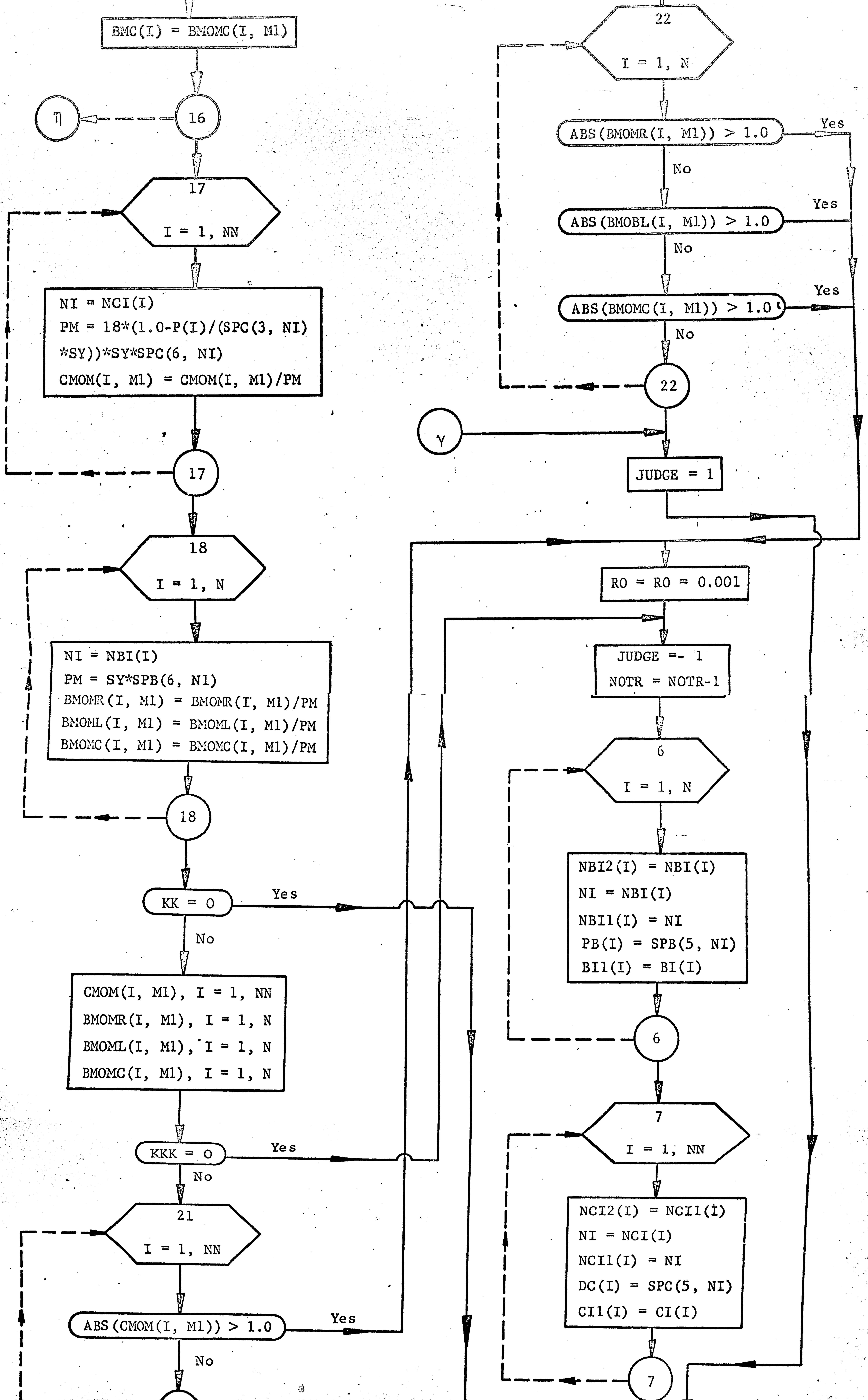

808
809
J = 1, NC
SPC1 = SPC(4, J)
Yes
No
XCM = 1.18*(1.0-P(N1)/(SPC(3, J)*SY))
* SY*SPC(6, J)
XCMO = 1.18*(1.0-1.7*WLDC(N1, M1)
/ (SPC(3, J)*SY))*SY*SPC(6, J)
RCM > XCM
ABS(CM(N1)) > XCM
ABS(XCM1) > XCMO
SPC(4, J) < CMI(N1, M1)
SPC(6, J) < ZC(N1, M1)
J = NC
WET1 = SPB(3, I)*SPR(N1) + SPC(3, J)*H
WET > WET1
WET = WET1
NCI(N1) = J
NBI(N1) = I
II = 1
809
812
β
812
II = 0
NI1 = NI1 - 10
1
813
NI = NCI(N1)
CI(N1) = SPC (4,NI)
NI = NBI(N1)
BI(N1) = SPB(4, NI)
BIR(N1) = BI(N1)
I = N1 + 1
BIL(I) = BI(N1)
RETURN


RCM = 0.5* ABS(BMR(N))
W54 = FIC(0.0)
WET = 1.0E + 1.0
XCM1 = (1.7*W(N)* XL(N)**2/16.0) /2.0
1
I = 1, NC
XCM = 1.8*(1.0-P(NN))/(SPC(3,I)*SY)
* SY*SPC(6, I)
XCMO = 1.18*(1.0-1.7*WLDC(NN, M1)/(SPC(3, I)
* SY))*SY*SPC(6, I)
ABS(CM(NN))2 XCM
Yes
No
RCM > XCM
Yes
No
XCM1 > XCMO
Yes
No
SPC(4, I) < CMI(NN, M1)
Yes
No
SPC(6, I) < ZC(NN, M1
Yes
No
WS4 > SPC(4, I)
Yes
No
WET1 = SPC(3, I)
WET1 > WET
Yes
No
WET = WET1
NCI(NN) = I
CI(NN) = SPC(4,I)
1
RETURN

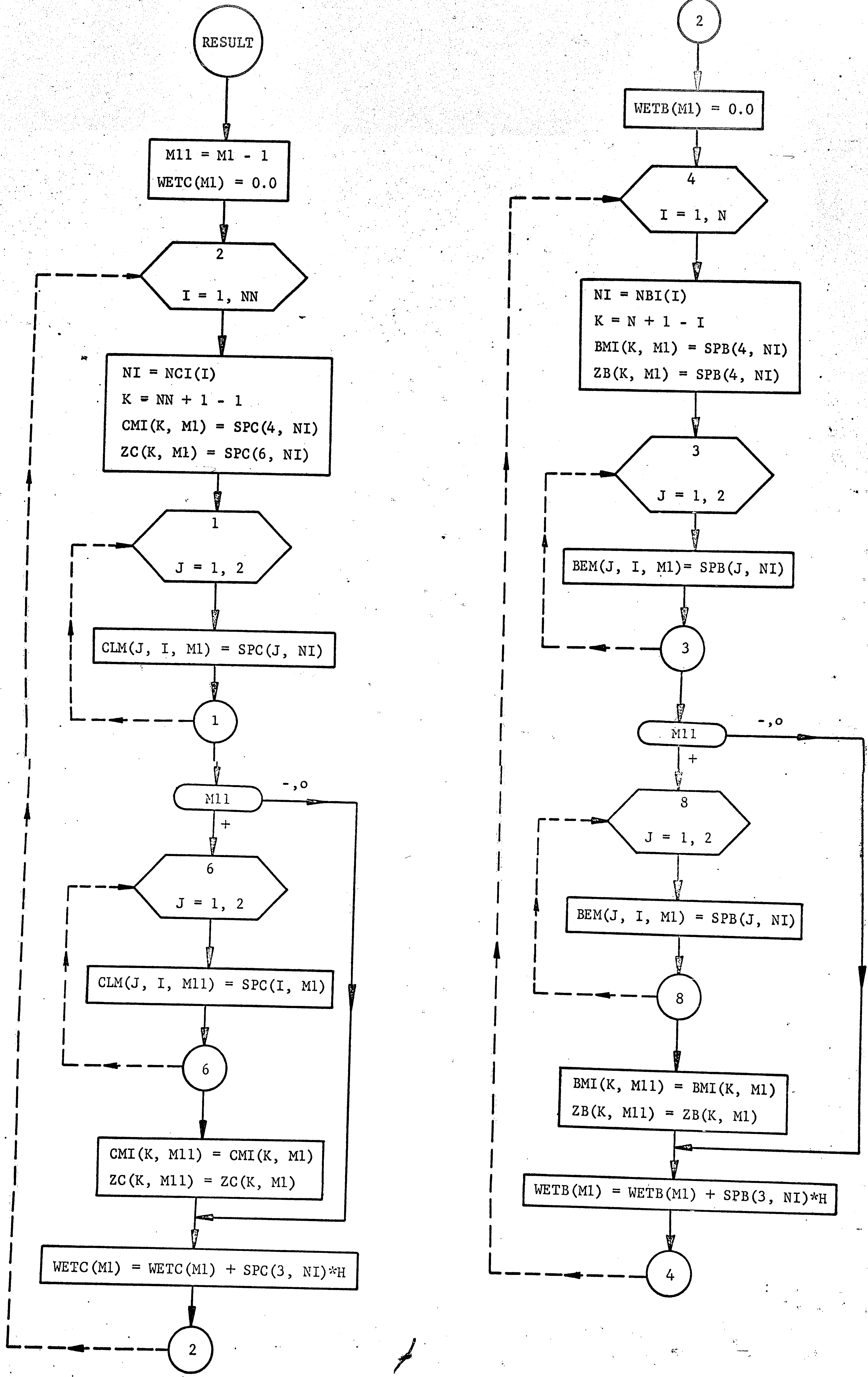

CHECK (JUDGE)
KK = 0
Yes
No
α
NOTR
NBI(I) I = 1, N
NCI(I) I = 1, NN
KKK = 0
901
I = 1, N
NBI1(I) = NBI(I)
No
901
902
I = 1, NN
NCI1(I) = NCI(I)
No
Yes
902
KKK = 1
α
9
I = 1, N
NBI2(I) = NBI(I)
No
α
Yes
9
9
24
I = 1, NN
NCI2(I) = NCI(I)
No
Yes
α
24
WETP1 = 0.0
WETP2 = 0.0
25
I = 1, N
NI = NBI1(I)
WETP1 = WETP1+XL(I)*SPB(3, NI)
NI = NBI2(I)
WETP2 = WETP2+XL(I)*SPB(3, NI)
25
26
I = 1, NN
NI = NCI1(I)
WETP1 = WETP1+H*SPC(3, NI)
NI = NCI2(I)
WETP2 = WETP2+H*SPC(3, NI)
26
WETP2 2WETP1
Yes
γ
No
β



27
I = 1, N
NBI(I) = NBI1(I)
27
28
I = 1, NN
NCI(I) = NCI1(I)
28
γ
α
CALL
MOMENT
CM(I), I = 1, NN
BMR(I), I = 1, N
BML(I), I = 1, N
10
I = 1, NN
CMOM(I, M1) = CM(I)
10
11
I = 1, N
BMOMR(I, M1) = BMR(I)
BMOML(I, M1) = BML(I)
CALL
MOM 1
CMC(I) I = 1, NN
BMR(I), I = 1, N
BML(I), I = 1, N
12
I = 1, NN
CMOM(I,M1) = CMOM(I,M1) + CM(I)
CM(I) = CMOM(I,M1)
12
13
I = 1, N
BMOMR(I, M1) = BMR(I)+SMOMR(I, M1)
BMOML(I, M1) = BML(I)+BMOML(I, M1)
BMR(I) = BMOMR(I, M1)
BML(I) = BMOML(I, M1)
13
ξ
16
I = 1, N
AX(I, M1) = 0.5-(BMOMR(I, M1)+BMOML(I, M1)
/(W(I)*XL(I)**2)
AX(I, M1)
o,+
AX(I, M1) = 0.0
BMOMC(I, M1) = BMOML(I, M1)
ζ
BMOMC(I, M1) = BMOML(I, M1)-(BMOML(I, M1)
+BMOMR(I, M1))*AX(I, M1)+W(I)*XL**2
*(AX(I, M1)-AX(I, M1)**2)/2.0



BMC(I) = BMOMC(I, M1)
η
16
17
I = 1, NN
NI = NCI(I)
PM = 18*(1.0-P(I)/(SPC(3, NI)
*SY))*SY*SPC(6, NI)
CMOM(I, M1) = CMOM(I, M1)/PM
17
18
I = 1, N
NI = NBI(I)
PM = SY*SPB(6, N1)
BMOMR(I, M1) = BMOMR(I, M1)/PM
BMOML(I, M1) = BMOML(I, M1)/PM
BMOMC(I, M1) = BMOMC(I, M1)/PM
18
KK = 0
Yes
No
CMOM(I, M1), I = 1, NN
BMOMR(I, M1), I = 1, N
BMOML(I, M1), I = 1, N
BMOMC(I, M1), I = 1, N
KKK = 0
Yes
No
21
I = 1, NN
ABS(CMOM(I, M1)) > 1.0
Yes
No
22
I = 1, N
ABS(BMOMR(I, M1)) > 1.0
Yes
No
ABS(BMOBL(I, M1)) > 1.0
Yes
No
ABS(BMOMC(I, M1)) > 1.0
Yes
No
22
γ
JUDGE = 1
RO = RO = 0.001
JUDGE =- 1
NOTR = NOTR-1
6
I = 1, N
NBI2(I) = NBI(I)
NI = NBI(I)
NBI1(I) = NI
PB(I) = SPB(5, NI)
BI1(I) = BI(I)
6
7
I = 1, NN
NCI2(I) = NCI1(I)
NI = NCI(I)
NCI1(I) = NI
DC(I) = SPC(5, NI)
CI1(I) = CI(I)
7


RESULT
M11 = M1 - 1
WETC(M1) = 0.0
2
I = 1, NN
NI = NCI(I)
K = NN + 1 - 1
CMI(K, M1) = SPC(4, NI)
ZC(K, M1) = SPC(6, NI)
1
J = 1, 2
CLM(J, I, M1) = SPC(J, NI)
1
M11
-,o
+
6
J = 1, 2
CLM(J, I, M11) = SPC(I, M1)
6
CMI(K, M11) = CMI(K, M1)
ZC(K, M11) = ZC(K, M1)
WETC(M1) = WETC(M1) + SPC(3, NI)*H
2
2
WETB(M1) = 0.0
4
I = 1, N
NI = NBI(I)
K = N + 1 - I
BMI(K, M1) = SPB(4, NI)
ZB(K, M1) = SPB(4, NI)
3
J = 1, 2
BEM(J, I, M1)= SPB(J, NI)
3
M11
-,o
+
8
J = 1, 2
BEM(J, I, M1) = SPB(J, NI)
8
BMI(K, M11) = BMI(K, M1)
ZB(K, M11) = ZB(K, M1)
WETB(M1) = WETB(M1) + SPB(3, NI)*H
4

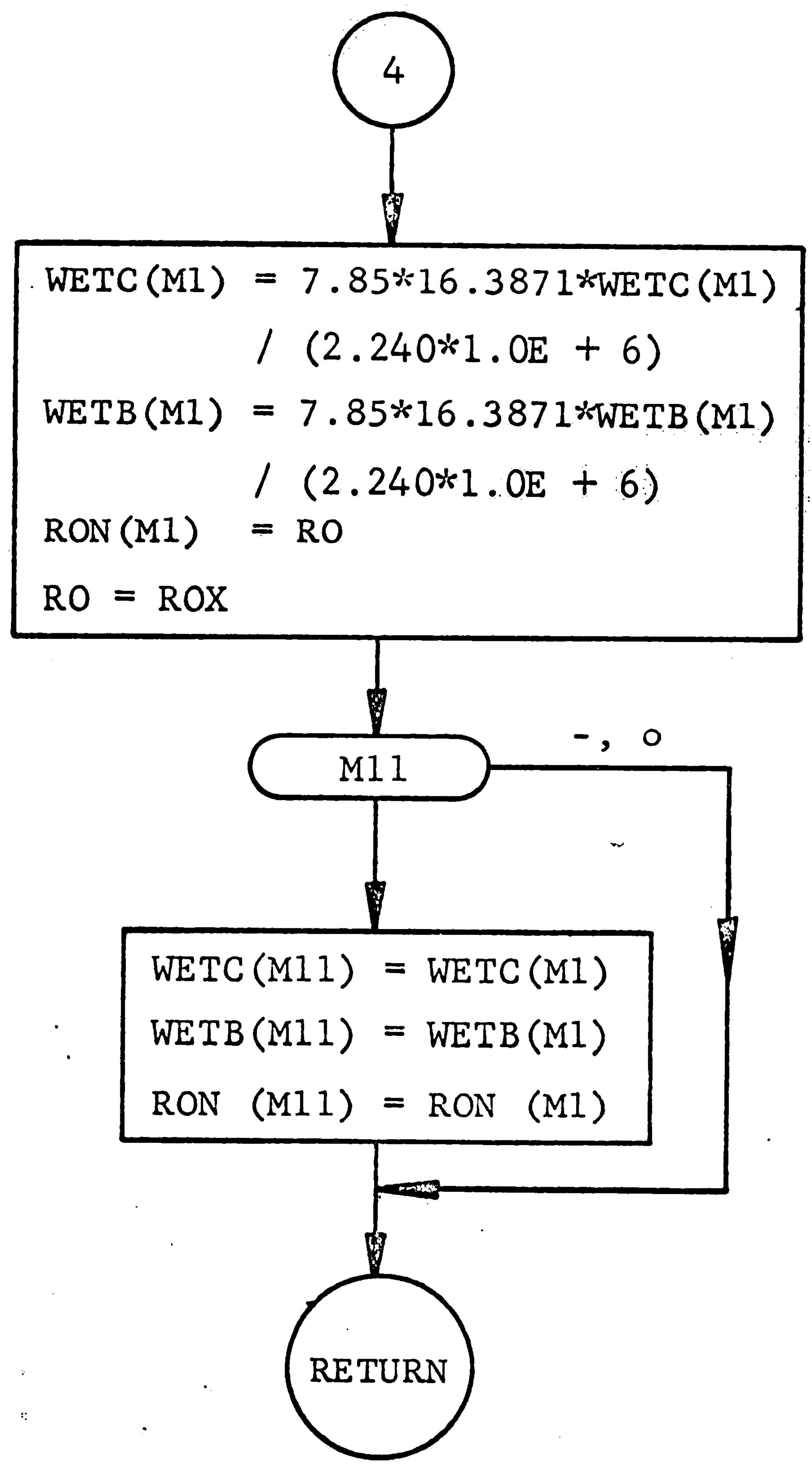
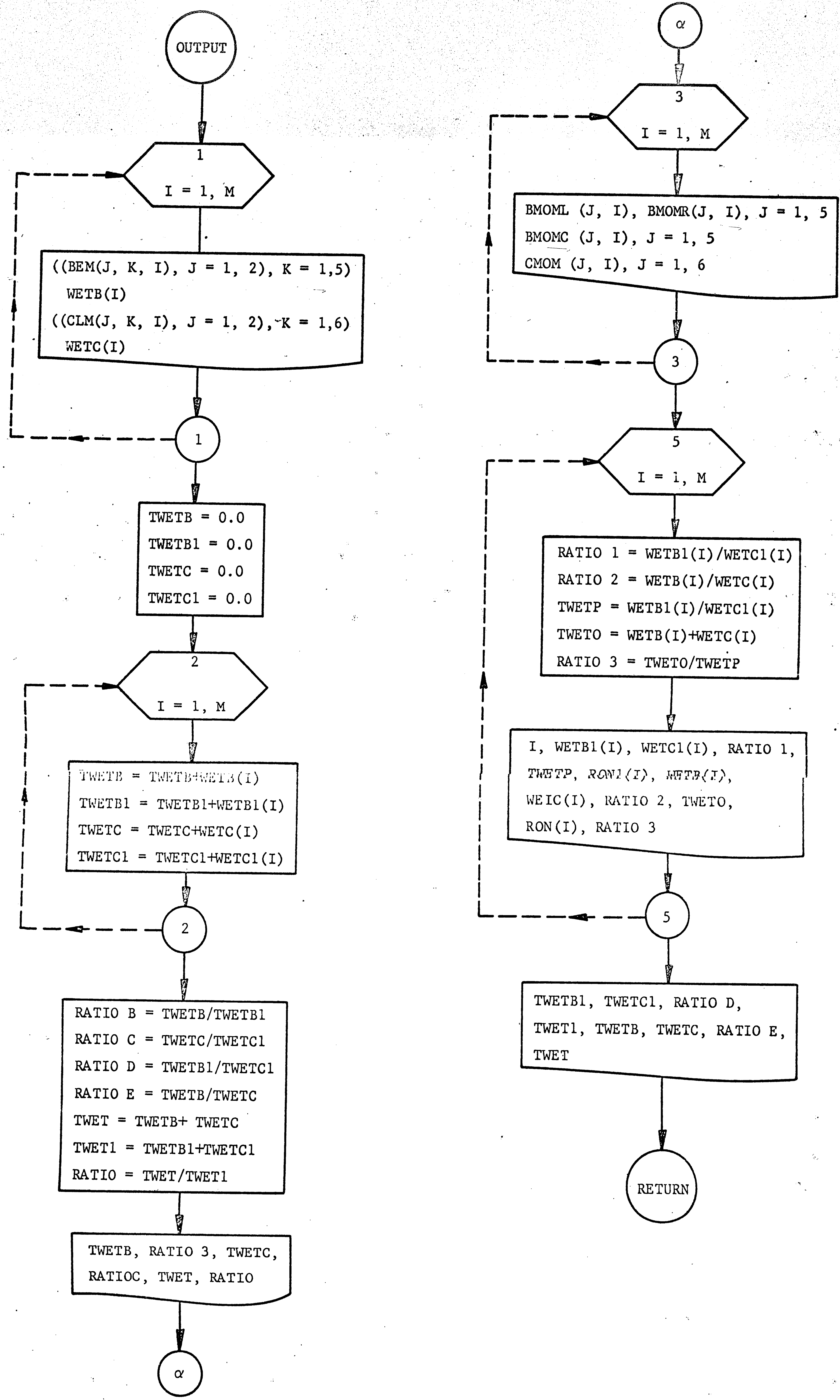
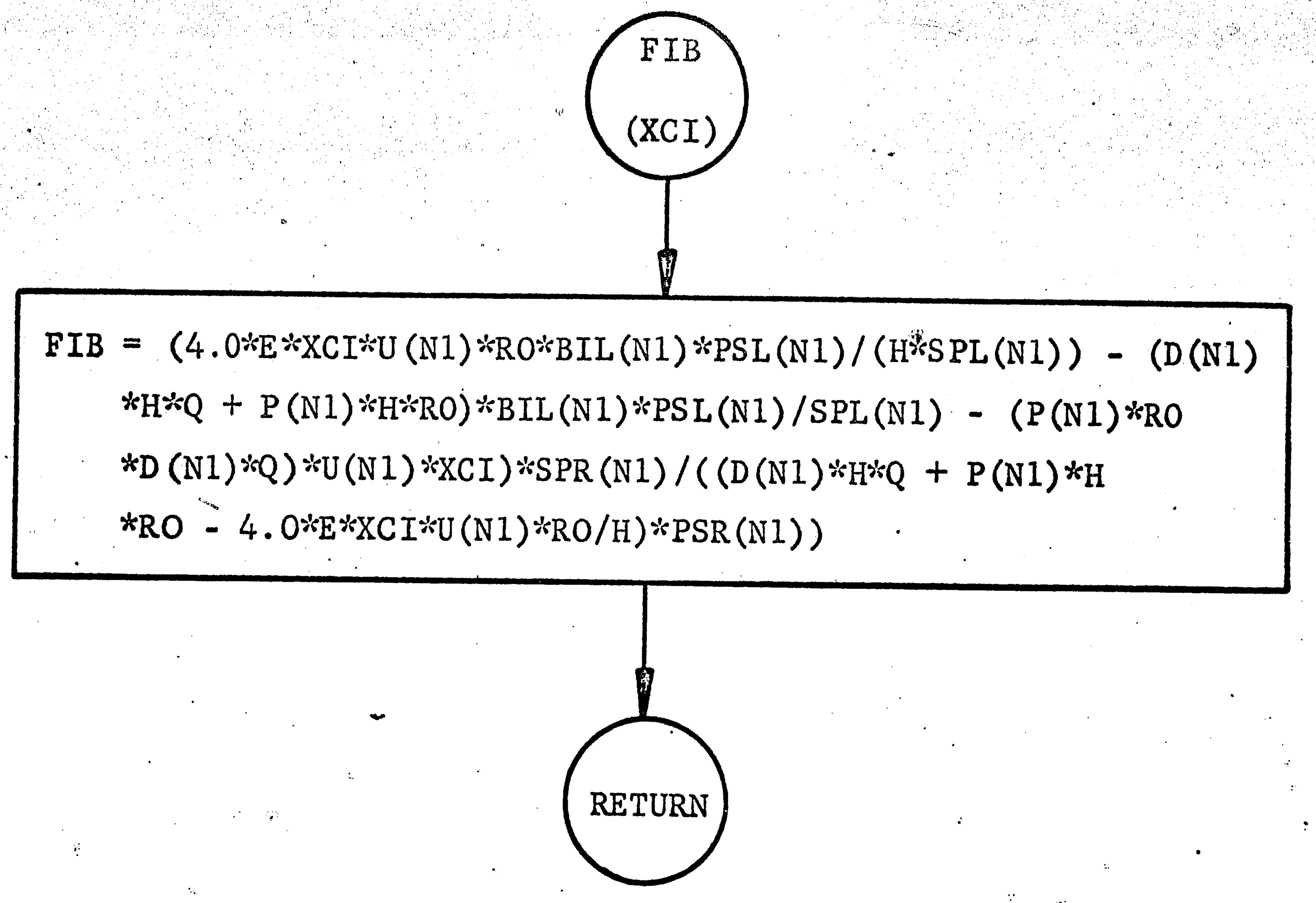


Fig. 4.25 Flow Chart of Subroutine RESULT (continued)


OUTPUT
1
I = 1, M
((BEM(J, K, I), J = 1, 2), K = 1,5)
WETB(I)
((CLM(J, K, I), J = 1, 2), K = 1,6)
WETC(I)
1
TWETB = 0.0
TWETB1 = 0.0
TWETC = 0.0
TWETC1 = 0.0
2
I = 1, M
TWETB = TWETB+WETB(I)
TWETB1 = TWETB1+WETB1(I)
TWETC = TWETC+WETC(I)
TWETC1 = TWETC1+WETC1(I)
2
RATIO B = TWETB/TWETB1
RATIO C = TWETC/TWETC1
RATIO D = TWETB1/TWETC1
RATIO E = TWETB/TWETC
TWET = TWETB+ TWETC
TWET1 = TWETB1+TWETC1
RATIO = TWET/TWET1
TWETB, RATIO 3, TWETC,
RATIOC, TWET, RATIO
α
α
3
I = 1, M
BMOML (J, I), BMOMR(J, I), J = 1, 5
BMOMC (J, I), J = 1, 5
CMOM (J, I), J = 1, 6
3
5
I = 1, M
RATIO 1 = WETB1(I)/WETC1(I)
RATIO 2 = WETB(I)/WETC(I)
TWETP = WETB1(I)/WETC1(I)
TWETO = WETB(I)+WETC(I)
RATIO 3 = TWETO/TWETP
I, WETB1(I), WETC1(I), RATIO 1,
TWETP, RON1(I), WETB(I),
WEIC(I), RATIO 2, TWETO,
RON(I), RATIO 3
5
TWETB1, TWETC1, RATIO D,
TWET1, TWETB, TWETC, RATIO E,
TWET
RETURN

TRANSP (I)
IND = 2
No
1
I = 1, N
WS1(I) = XL(N+1-I)
1
2
I = 1, N
XL(I) = WS1(I)
2
3
I = 1, N
WS1(I) = W(N+1-I)
3
4
I = 1, N
W(I) = WS1(I)
4
7
I = 1, M
5
J = 1, NN
WSI(J) = WLDC2(NN+1-J, I)
5
6
J = 1, NN
WLDC2(J, I) = WSI(J)
6
7
β
12
I = 1, M
11
K = 1, 2
9
J = 1, NN
WSI(J) = CLM(K, NN+1-J, I)
9
10
J = 1, NN
CLM(K, J, I) = WS1(J)
10

15
K = 1, 2
13
J = 1, N
WS1(J) = BEM(K, N+1-J, I)
13
14
J = 1, N
BEM(K, J, I) = WS1(J)
14
15
18
J = 1, N
WS1(J) = BMOMR(N+1-J, I)
18
19
J = 1, N
BMOMR(J, I) = WS1(J)
19
20
J = 1, N
WS1(J) = BMOML(N+1-J, I)
20
21
J = 1, N
BMOML(N+1-J, I) = WS1(J)
21
22
J = 1, N
WS1(J) = BMOMC(N+1-J, I)
22
23
J = 1, N
BMOMC(J, I) = WS1(J)
23
24
J = 1, NN
WS1(J) = CMOM(NN+1-J, I)
24



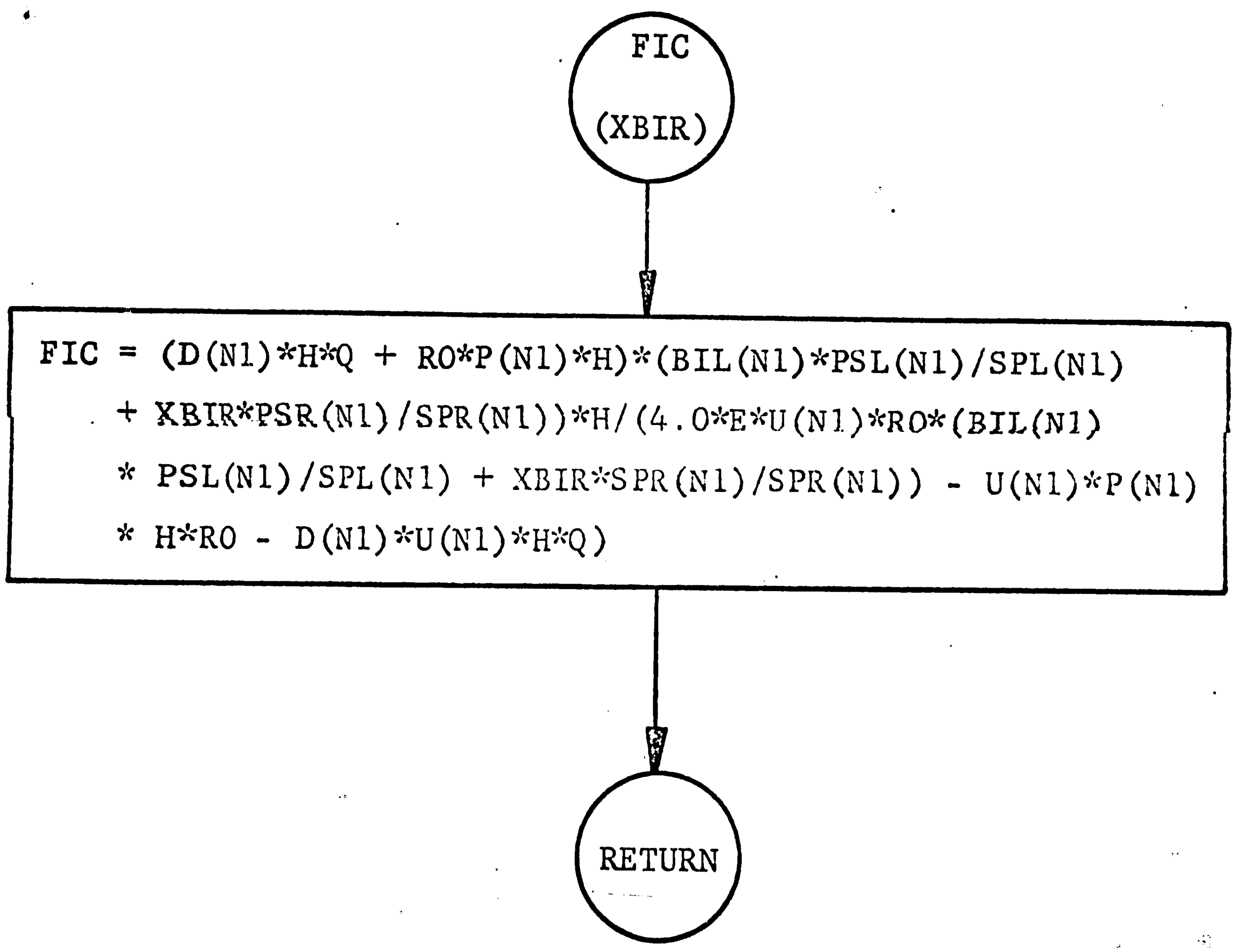
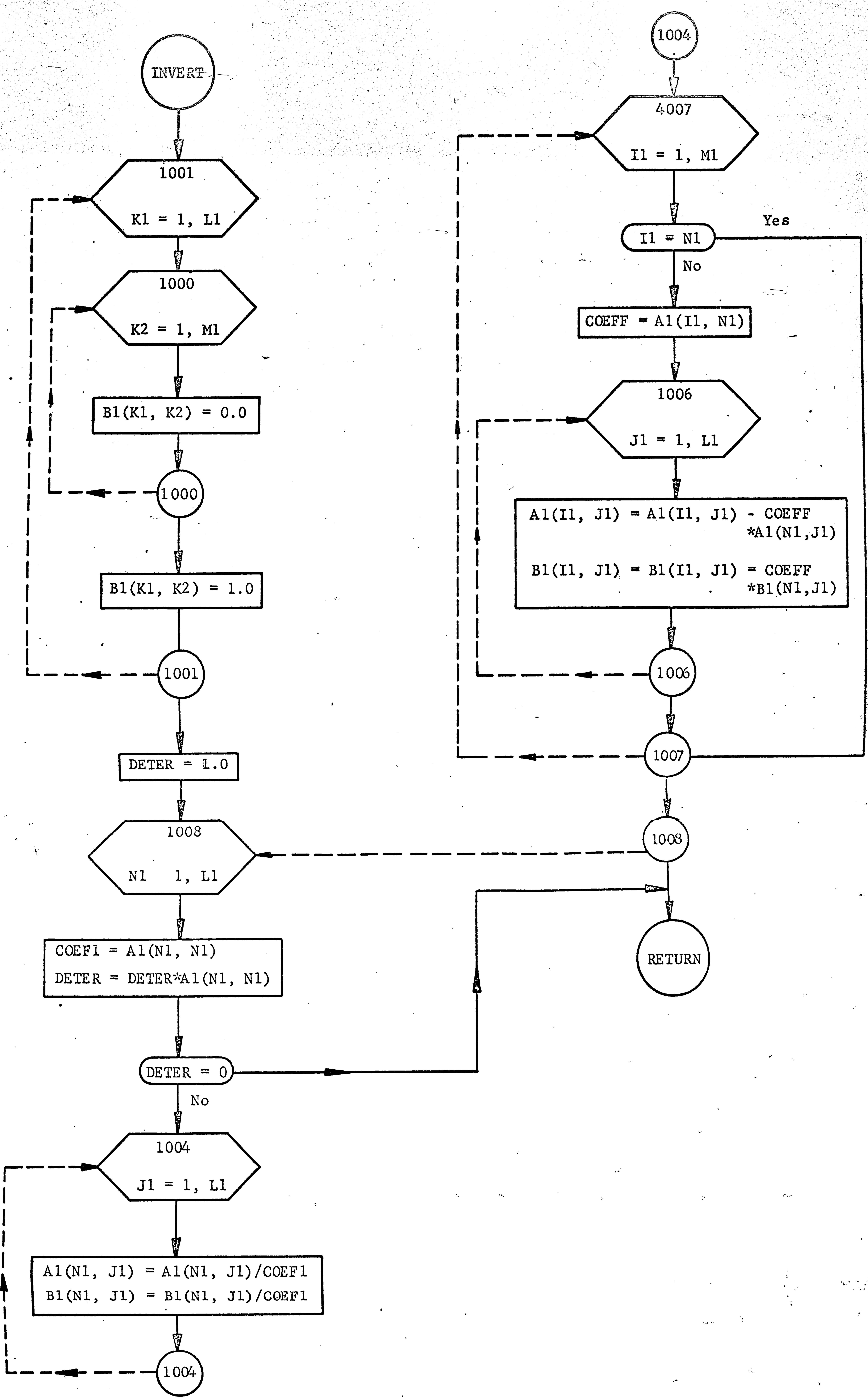


Fig. 4.29 Flow Charts of Functions FIB and FIC



INVERT
1001
K1 = 1, L1
1000
K2 = 1, M1
B1(K1, K2) = 0.0
1000
B1(K1, K2) = 1.0
1001
DETER = 1.0
1008
N1 1, L1
COEF1 = A1(N1, N1)
DETER = DETER*A1(N1, N1)
DETER = 0
No
1004
J1 = 1, L1
A1(N1, J1) = A1(N1, J1)/COEF1
B1(N1, J1) = B1(N1, J1)/COEF1
1004
1004
4007
I1 = 1, M1
I1 = N1
Yes
No
COEFF = A1(I1, N1)
1006
J1 = 1, L1
A1(I1, J1) = A1(I1, J1) - COEFF
*A1(N1,J1)
B1(I1, J1) = B1(I1, J1) = COEFF
*B1(N1,J1)
1006
1007
1008
RETURN

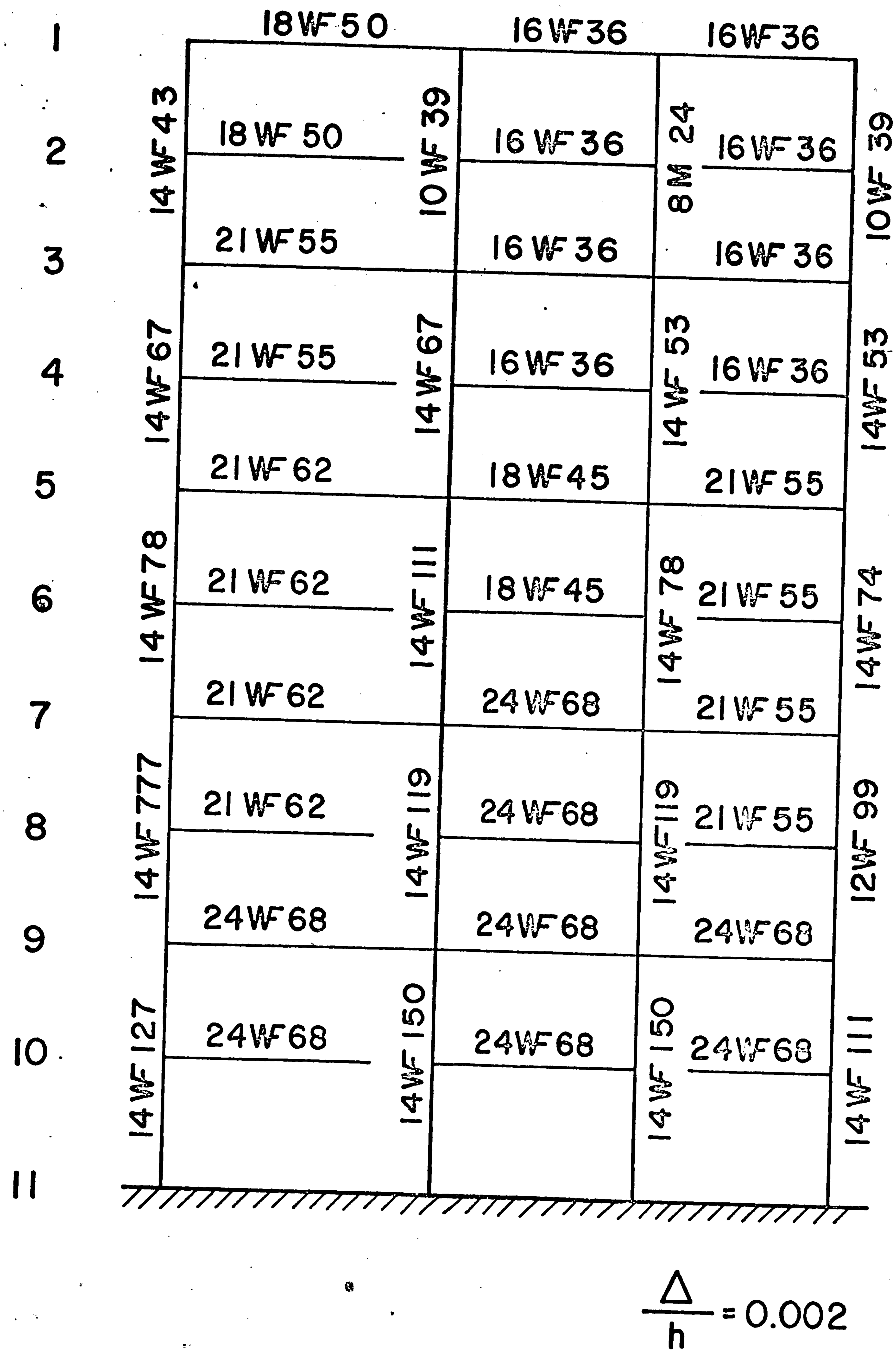


Fig. 5.1 Minimum Weight Design Frame
(Sway Limitation $\frac{\Delta L}{h} = 0.002$)

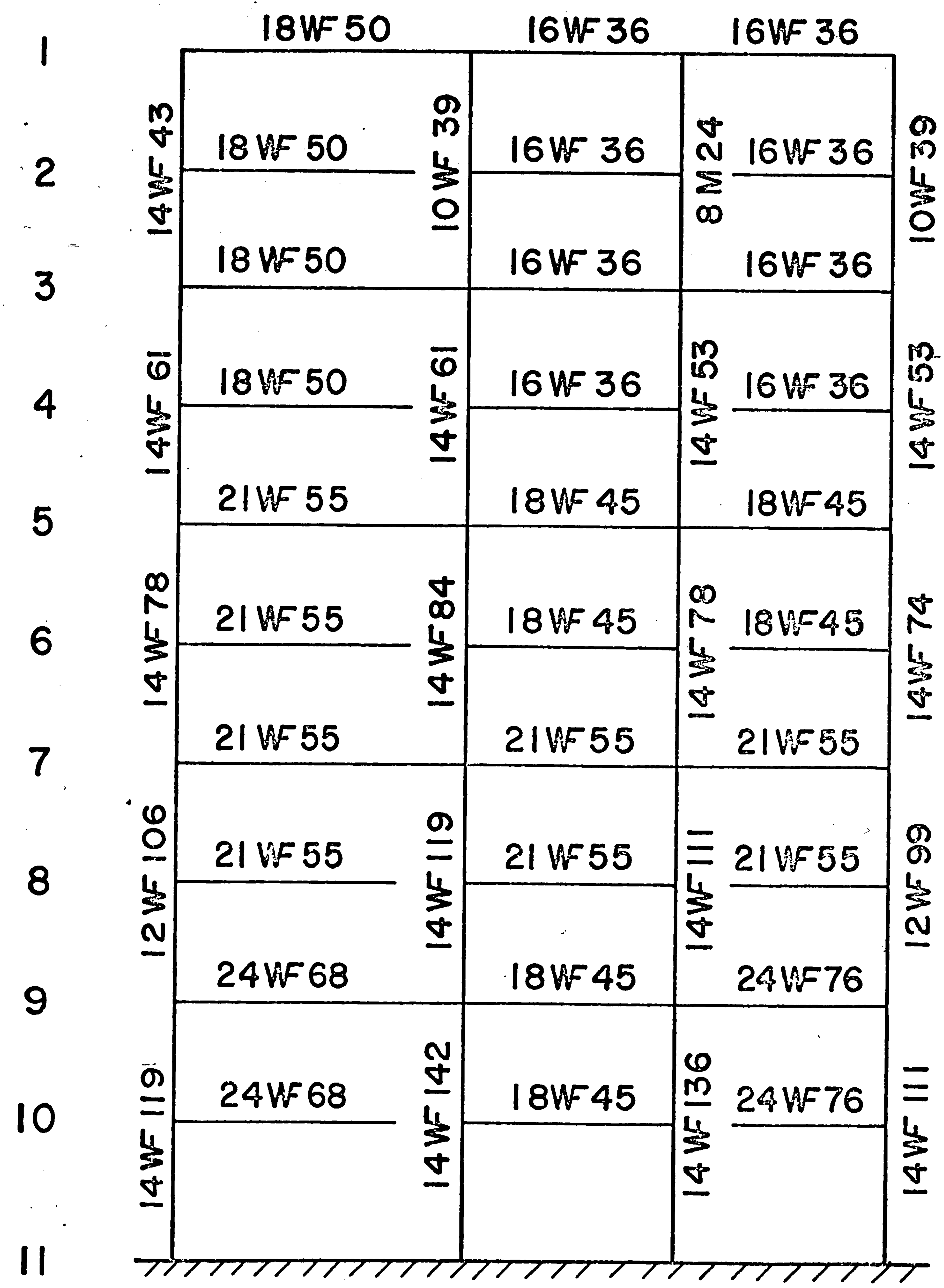


Fig. 5.2 Minimum Weight Design Frame
(Sway Limitation $\frac{\Delta L}{h}$ = 0.0025)

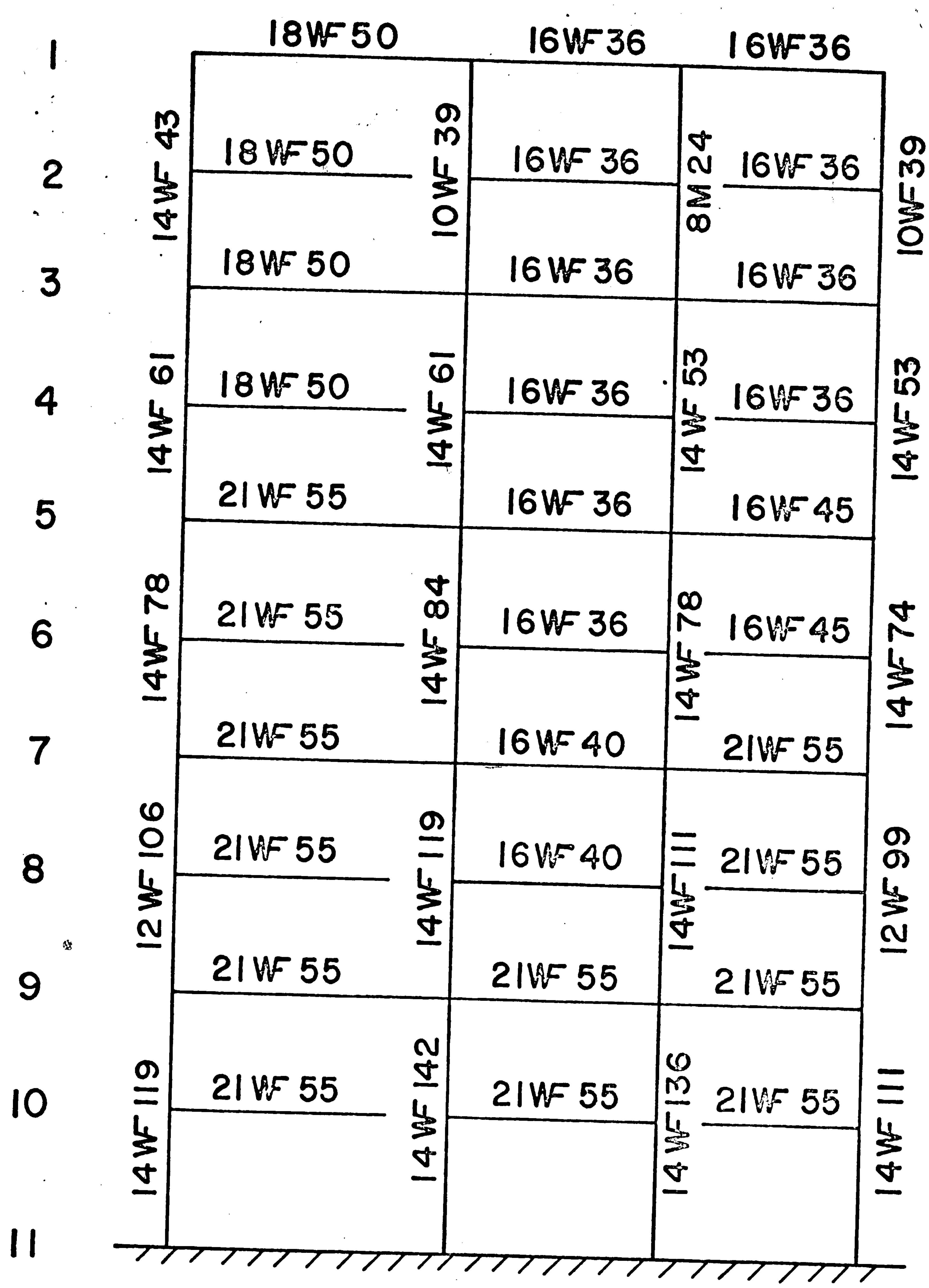


Fig. 5.3 Minimum Weight Design Frame

(Sway Limitation $\frac{\Delta L}{h} = 0.003$)

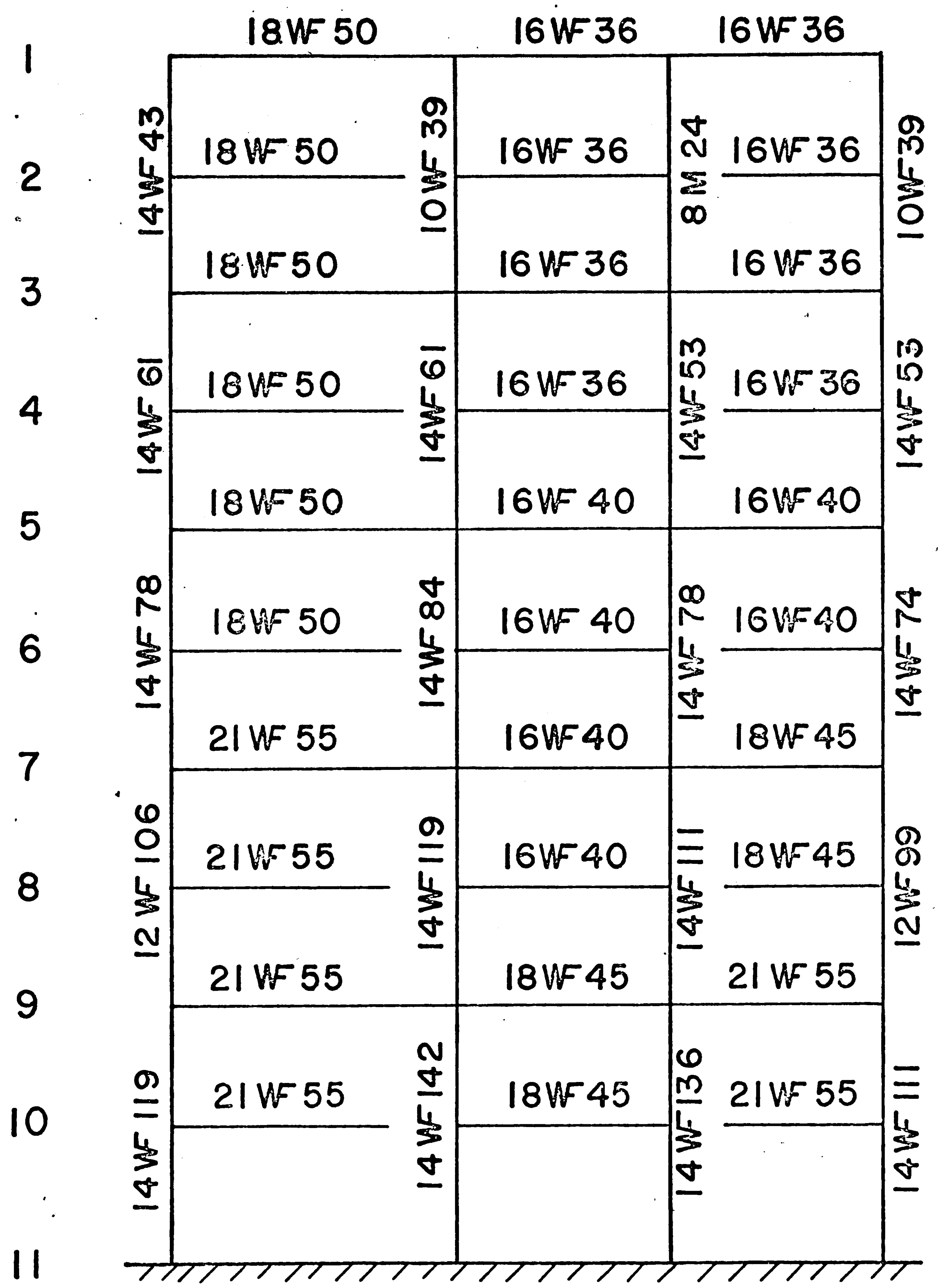


Fig. 5.4 Minimum Weight Design Frame

(Sway Limitation $\frac{\Delta L}{h} = 0.004$)

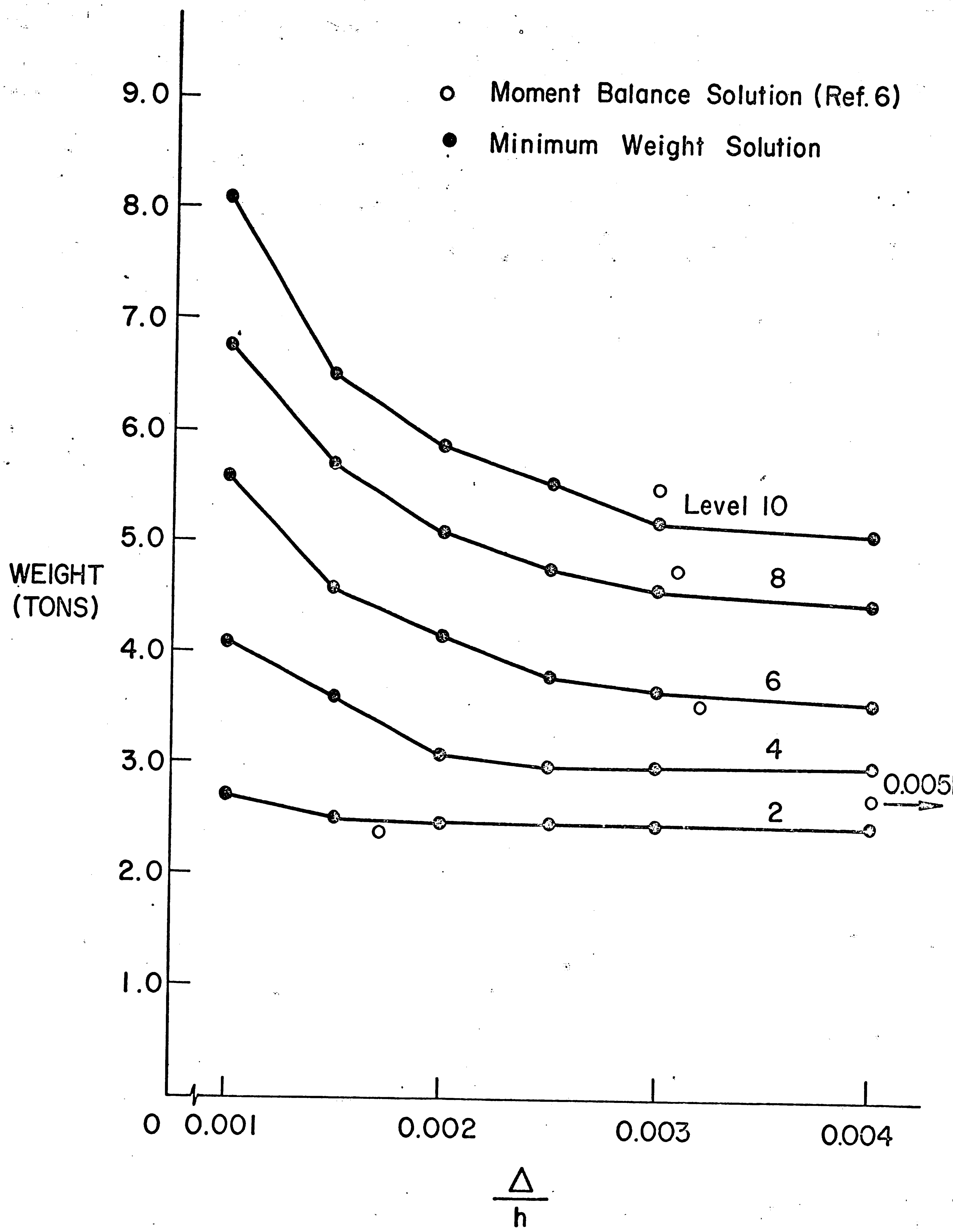


Fig. 5.5 The Relationship between Weight of One Story Assemblages and Sway Limitations

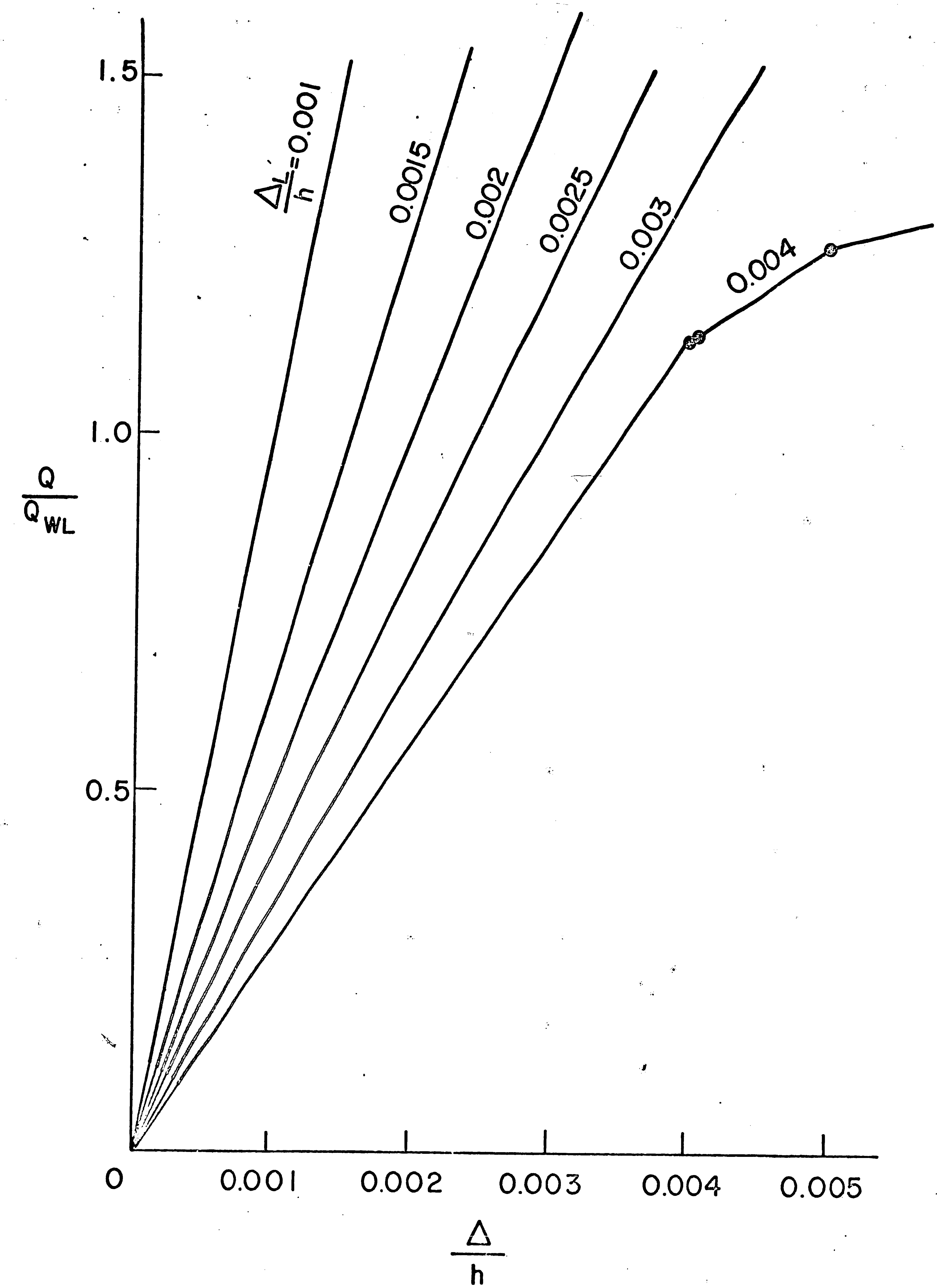


Fig. 5.6 Horizontal Force Versus Sway Deflection Under the Working Combined Load (Level 8)

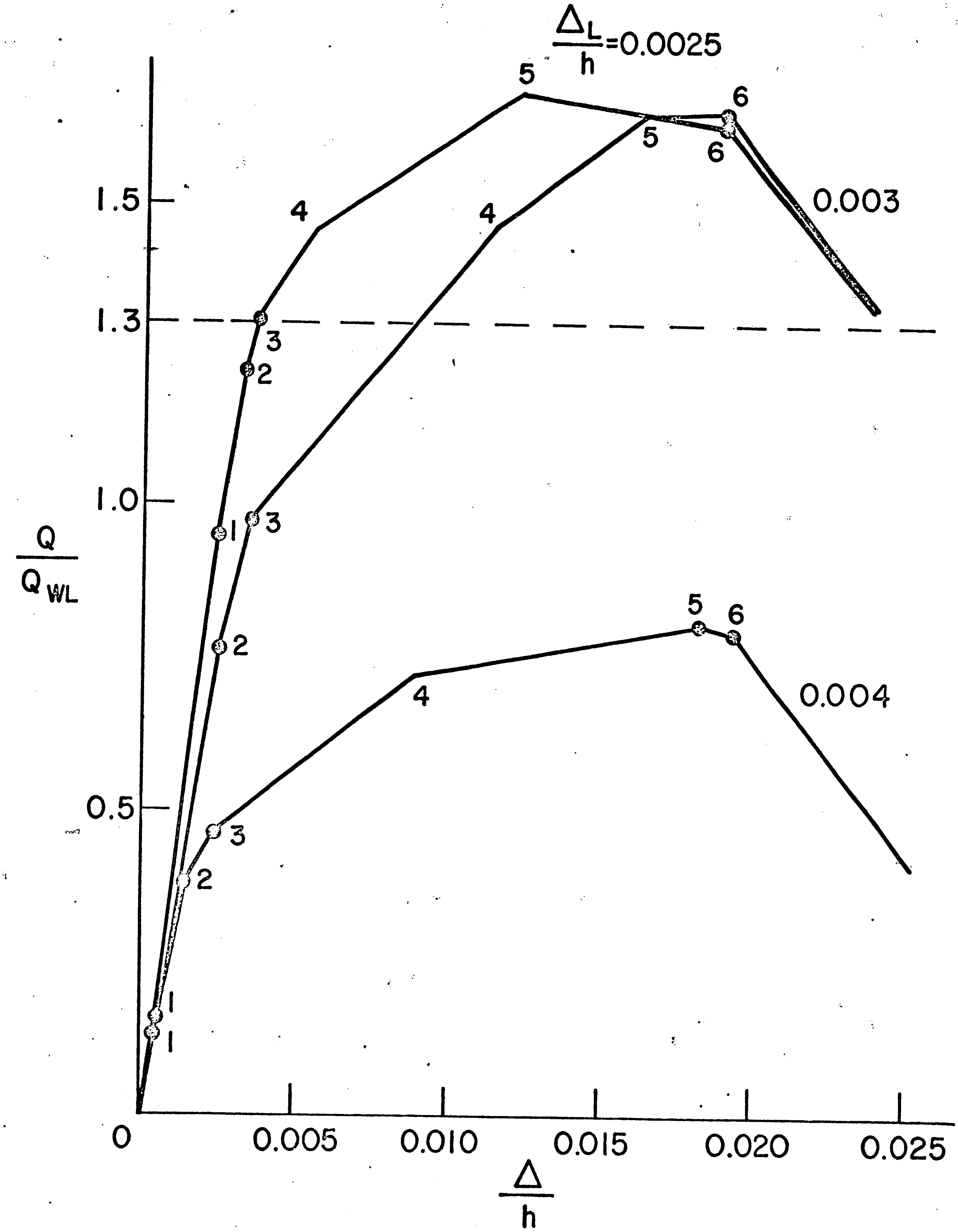


Fig. 5.7 Horizontal Force Versus Sway Deflection Under Factored Combined Load (Level 6)

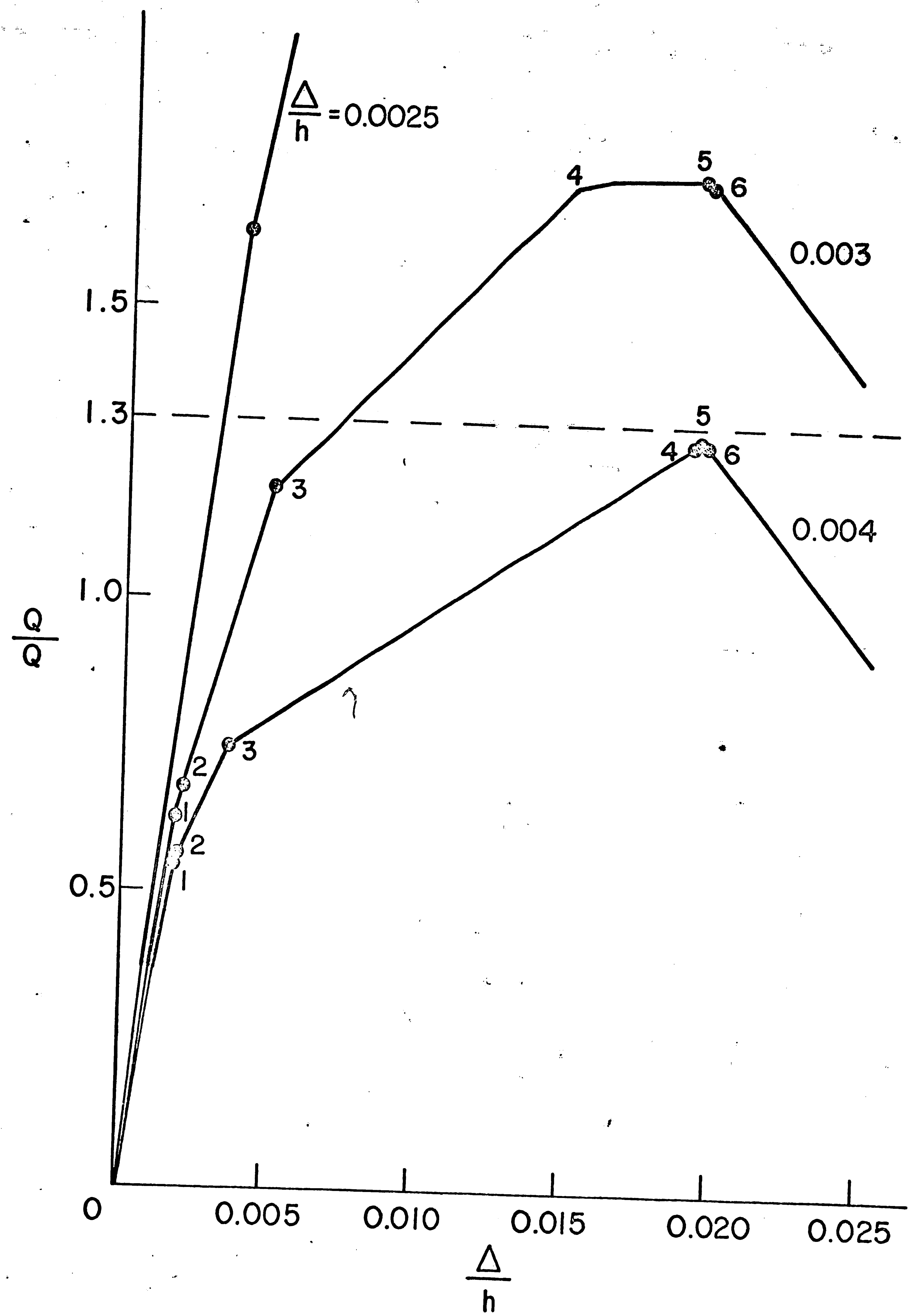


Fig. 5.8 Horizontal Force Versus Sway Deflection
Under Factored Combined Load (Level 8)

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